B
2.50

Theodore Lyman

THE SCIENCE AND PRACTICE OF PHOTOGRAPHY

AUTOCHROME PHOTOGRAPH

THE SCIENCE AND PRACTICE OF PHOTOGRAPHY

AN ELEMENTARY TEXTBOOK ON THE
SCIENTIFIC THEORY AND A
LABORATORY MANUAL

BY

JOHN R. ROEBUCK, Ph.D.

ASSISTANT PROFESSOR OF PHYSICS IN THE
UNIVERSITY OF WISCONSIN

ILLUSTRATED

D. APPLETON AND COMPANY

NEW YORK LONDON

1919

Printed in the United States of America

PREFACE

Many students are attracted by a course in photography who have had little acquaintance with science and less understanding of its spirit. There is no reason why the methods of modern science, as well as its attitude, cannot be taught by a course in photography as well as by a course in quantitative chemistry or in the theory of electricity. It has the enormous advantage over many other subjects of starting with a vigorous curiosity on the part of the student, and of maintaining his interest by the strong desire to master the subject for his own use. In all the author's experience there has been no opening for criticism of the amount of work his students were willing to do; the difficulty has been to keep the laboratory closed at unreasonable hours.

The methods of science are necessarily quantitative where such methods can be applied. The quantitative study of the dry plate offers a very attractive example to induce the student to chew with some relish the tough grist of close thinking. For the student who has already developed some powers of mastication, the case is not particularly difficult, and its understanding is absolutely necessary for an intelligent use of any of the photographic processes. No collection of apparently empirical rules can take its place. It was this attitude, determining the treatment, which persuaded the author to undertake this text. Also the available books offered nothing at all suitable for a laboratory manual where even a small number of students were to be cared for. In consequence, the broad treatment as well as the

details are the product of experimental selection in this laboratory. The course has now been given for seven years, during which time both text and laboratory manual have been rewritten twice in mimeograph form, besides receiving innumerable additions and corrections. The author hopes that this summary of his experience will be found of value to other instructors and students, as well as to many not in university work yet who are interested in the real understanding of their subject.

While the primary purpose of the book is a class-room text, the author has aimed to make it useful to many earnest amateurs by collecting and systematizing for them material now widely scattered through the literature of photography. For the aid of such workers and for the instructor many references are given to the literature which will draw attention to and aid in the study of the original work.

In the *British Journal Almanac* for 1916 (at page 503) will be found a list of the journals of the world which print photographic information. For an English-speaking worker the most generally useful are: the *British Journal of Photography* (U. S. agent, George Murphy, 59 E. 9th Street, New York), the *Journal of the Royal Photographic Society* (Harrison and Sons, 45 Pall Mall, London, S. W.), the *Photo Miniature* (Tennant and Ward, New York), *American Photography* (221 Columbus Avenue, Boston, Mass.), and possibly still more popular ones, as the *Photo Era* and the *Camera.*

Any teaching in science should keep before the student that he is just beginning and that the most experienced worker carries in his head but a small proportion of the known facts and even of the accepted generalizations relating to his subject. The literature is the record of all this information, and the sooner a student can be brought to turn to it for chance reading as well as for information on specific problems, the more satisfactory will his progress

be. It is not easy to get him interested to the extent that he will read voluntarily, and it will aid materially if a few current numbers of the scientific as well as the more popular journals are kept in the laboratory, where they will be seen thus announcing their existence and be picked up during waiting moments. For the library it hardly needs saying that the more current journals in all languages that are kept, and the more complete the files of back numbers, the better for the real worker.

To some not directly in touch with research it may be advisable to point out some justification for burdening the practical photographer with so much work in mathematics, in physics, and in chemistry. There is no doubt that many photographers doing excellent technical work know very little of these subjects whose application is the basis of the methods they use. This last statement contains the justification, and if an experimental proof is desired, it is only necessary to point out the painfully slow progress of the methods of time and factorial development in ousting the old-time guess work with the tray. Further, if there were an intelligent demand from the user, manufacturers would soon mark their plates with the actual development speeds and the actual sensitiveness. Hardly anyone doubts that the empirical worker could have acquired his skill with less experience, and could probably improve it now, by understanding the relationships among the variables with which he works.

The course as outlined in this book requires an elementary knowledge of mathematics, of physics, and of chemistry. Good high-school algebra as well as good high-school courses in physics and in chemistry will be found sufficient to enable the student to take the further steps required.

No extended description of the common photographic apparatus is included in the text since it can be given much

better by the instructor with the apparatus beside him. The student finally becomes familiar with it by use. Any discussion of the variations, with uses and advantages, would extend the text unprofitably.

The discussion of lenses has to stop short of any real mathematical treatment for which the average undergraduate has no preparation. There are many excellent special treatises now to be had. The careful testing of lenses requires an expensive optical outfit, some advanced mathematics, and considerable practice. In any case the main problems of the young photographer are not with his lens performance, and very few expert photographers are competent to pass upon the optical questions involved; hence it has seemed profitable to limit the discussion of lenses to practically that contained in a good book on college physics.

The number of photographic reproductions in the text has been limited by consideration of the fact that they are reproductions varying necessarily in character from the originals, and by the fact that negatives and positives themselves should be displayed in the laboratory and the instructor should call attention to the points in the student's own work.

My thanks are due to Mr. R. C. Williamson, who so ably assisted me for three years in giving this course, and to whose criticism and suggestion many improvements in both laboratory course and text are due.

JOHN R. ROEBUCK.

Physics Laboratory
University of Wisconsin
1917

CONTENTS

PART I

GENERAL THEORY

APPENDIX

PART II

LABORATORY MANUAL

APPENDICES

PART I

GENERAL THEORY

CHAPTER I

HISTORICAL DEVELOPMENT

1. **The beauty and utility of an image** formed by a lens or curved mirror inspires every observer with the desire to make it permanent. The direct method for accomplishing this is to have the light forming the image act upon some substance in such a way as to leave a record. The history[1] of photography begins probably with the observation of the action of light on substances, and a great variety of such observations are recorded. In particular the Swedish chemist, Scheele, studied the action of light on silver chloride, proving the decomposition of the substance, thus

$$AgCl = Ag + Cl$$

Along with such observations one must place also studies on lenses and on the *camera obscura.* The idea of the latter is attributed to an Italian in the sixteenth century. A certain amount of chemical

[1] For more detail in the history, see W. J. Harrison, "History of Photography."

knowledge was essential to progress in photography, particularly the chemistry of the salts of silver which have always occupied the leading place among the substances affected by light. Toward the end of the eighteenth century chlorine, bromine, and iodine had all been discovered and studied so that Sir Humphry Davy and Thomas Wedgwood were able to experiment more intelligently than their predecessors. They coated plates with the salts of silver, silver nitrate, silver chloride, silver bromide, and silver iodide, and, exposing them to light, made pictures. They discovered that the action of light differed somewhat with the different substances used and with the color of the light allowed to fall upon them. But they could not make their pictures permanent, as they knew of no way to remove the unacted on silver salt, so that exposure to light in the course of time turned it all black.

2. **Niépce.**—Following this a Frenchman, Niépce, succeeded in making pictures by using the fact that light renders bitumen insoluble in certain oils (probably on account of the oxidation of the bitumen—compare the present day carbon process). He coated a metallic surface with a layer of the bitumen and exposed it to light in a camera sometimes for a whole day, and then with the oil washed away the parts still soluble. Since all the insoluble

part was on the surface and the remaining soluble part next the metal, this washing removed all the fine lines (detail) where the insolubility did not extend right through to the metal. Nevertheless he obtained permanent pictures and probably the first ones.

3. **Daguerre.**—Later Niépce and Daguerre worked together in partnership but it was not till after the former's death that Daguerre succeeded in making permanent pictures. Neglecting variations during the process of discovery, the final process consisted in making a polished silver plate, exposing it to iodine vapors, thus forming silver iodide on the surface. This plate was then exposed in the camera, and later developed by exposing to the vapor of mercury, this process of development being discovered by Daguerre quite by accident but followed up with great skill. The picture was then fixed, early in the work by boiling in strong sodium chloride solution, but later, when the solvent action of sodium hyposulphite solution on the salts of silver was pointed out to him, he changed over to it. The compound itself as well as its action on the salts of silver had only been discovered a few years before. The pictures were very fine, full of detail, and more permanent than most of our prints now. It quickly leaped into popularity and won a pension for Daguerre from the French government. Good

1839

See Derr p. 120

mercury-silver amalgam

Mercury deposits where the [illegible]

examples may still be seen. The exposure was of the order of five minutes, but this was lessened later by using a mixture of the haloids, chlorine, bromine, and iodine, instead of iodine alone, to act on the silver plate. This process held the field for about 15 years, when it was displaced by the collodion process.

4. **Talbot.**—At this same time, 1840-1850, Talbot in England worked out a process which was in some respects superior to Daguerre's though not on the whole. Paper was brushed over with silver nitrate solution and dried. It was then wet in potassium iodide solution and made still more sensitive to the action of light by soaking in a gallic acid solution—this really acting also as a developer. He fixed them at first by soaking in potassium bromide solution but later used hyposulphite solution. This gave a negative, and by waxing or oiling the paper, it was possible to lay it on another piece of paper similarly treated and by exposing to light make a print which was a positive. The process allowed of duplication and was cheaper than Daguerre's, but the latter were much finer in detail and more permanent, so that the Daguerreotypes held the popular fancy, and Talbot's process was never generally used.

During these years Herschel suggested the use of glass for support of the sensitive substance, and

a second Niépce actually covered a plate with albumen to hold the silver salt, but the exposure was long,—5-10 minutes, and the process did not attract much attention.

5. **Wet Collodion.**—The foundation for the collodion process [2] was laid when the Swiss chemist, Schönbein, discovered the action of nitric and sulphuric acids on ordinary cotton. Acting for a long time with very concentrated acid makes guncotton an explosive, but if for a shorter time or in more dilute solution it forms a substance called soluble pyroxyline. A solution of this in a mixture of alcohol and ether is called collodion, and is still used in surgery for covering up cuts and abrasions, as it dries to a strong film. The soluble pyroxyline mixed with some camphor makes celluloid. Scot Archer applied these discoveries of soluble pyroxyline in the collodion process, which, as it came from his hands, quickly displaced all previous processes. It held the field till about 1880 and is still used in many of the photo-engraving establishments. Either the soluble pyroxyline or its solution called collodion can now be bought from photographic supply houses, but for many years the photographer had to make his own pyroxyline by soaking cotton in a

[2] For an excellent detailed description of the modern process, see Foxlee, "Wet Collodion Process," *British Journal*, 54, 483 (1907).

mixture of equal parts of nitric and sulphuric acids and washing thoroughly. The product was dissolved in a mixture of alcohol and ether, a little soluble iodide and bromide added, and a film formed on clean glass by pouring the solution onto the glass plate so as to cover it all, and letting the excess drain off while the rapidly drying material left a coating on the glass surface. As soon as the film hardened it was dipped in a solution of silver nitrate, thus precipitating silver bromide and silver iodide in the film. It was exposed while wet and developed while yet wet by a ferrous sulphate solution, which reduced to metallic silver the silver haloid which has been acted on by light. The plate was fixed by flooding it with a solution of sodium hyposulphite, in strong solution, which dissolves out the unacted on silver haloid. Many workers preferred a solution of potassium cyanide for this purpose but it is exceedingly poisonous. The plate was finally washed in water. These reactions may be represented in chemical symbols thus,

Compare Darr p 120

$$AgNO_3 + KBr = KNO_3 + AgBr$$

and

$$AgNO_3 + KI = KNO_3 + AgI$$

and in development

$$FeSO_4 + AgBr = Ag + Fe(SO_4)Br$$

On attempting to fix in weak hypo solution

$$AgBr + Na_2S_2O_3 = NaBr + AgNaS_2O_3 \text{ (insoluble)}$$

and in strong hypo solution

$$2AgBr + 3Na_2S_2O_3 = 2NaBr + Ag_2Na_4(S_2O_3)_3 \text{ (soluble)}$$

and in potassium cyanide solution

$$AgBr + 2KCN = KBr + KAg(CN)_2 \text{ (soluble)}$$

This process is a difficult one on account of the great care required, but it gives beautiful negatives, very clear with abundant detail, and is still unexcelled for lantern slides. For the enthusiast it has the advantage that the whole process is entirely in his own hands and also for this reason gives the clearest laboratory insight to the photographic process. We will spend a short time on it in the laboratory. (See Exp. 20.)

6. **Collodion Emulsions.**—On account of the difficulty of handling the plates wet, persistent efforts were made to perfect some way to use them dry, but the sensitiveness to light was always much reduced, though a goodly number of ways were worked out as possible. The best of these modifications, which might have held the field but for the gelatine plate, was Bolton's "Washed Collodion Process."[8] The collodion with soluble bromide in it, not iodide, was mixed with silver nitrate dis-

[8] See also article on Orthochromatic Collodion Emulsions in *British Journal*, 55, 418 (1908).

solved in alcohol. The resulting liquid is called an emulsion on account of its resemblance to a well-shaken mixture of oil and water. It is filled with fine particles of silver bromide, which is not soluble in the alcohol-ether mixture, and besides, holds in solution the other products of the reaction as well as possibly some silver nitrate if it was present in excess. The emulsion was then dried in a thin layer and thoroughly washed to remove the soluble salts, dried and again dissolved in the alcohol-ether, when it was ready for coating the plates, which were used after they were dry, but were moistened again with silver nitrate solution before development. Plates made on this plan were on the market for some years. The great difficulty with all these dried collodion plates is that the collodion dries to such a hard and compact film that it does not absorb the solutions used for development.

7. **The development of the gelatine dry plate** soon put all these processes out of use except for very special purposes. A great many early workers experimented with gelatine, but with many failures till about 1880, when the plates were perfected sufficiently to outclass the collodion so completely as to displace it in three or four years, their great advantages being their keeping qualities, portability, and speed. It will be sufficient for our purpose to describe one method for making gelatine plates and

not to attempt to trace the modifications during discovery.

8. **Gelatine** itself is a very interesting substance.[4] It is obtained from animal tissue, horns, skin, hoofs, etc., by digesting them in hot water, for the high-grade gelatine without boiling, but for the lower grades and for glue even heating in a closed boiler under pressure. It has to be freed as completely as possible from all fat and also from all inorganic salts. Isinglass is made from the air bladder of a fish, the sturgeon, in much the same way. Gelatine belongs to the class of bodies called colloids; it is made up principally of two substances, both organic and nitrogenous, called glutin and chondrin, the former being in excess in photographic gelatines, making them set more readily and melt at a higher temperature—that is "hard" gelatine. Dried in the air it still retains 15-20% of water, and if put in water it swells up, absorbing several times its own volume of water, becoming very soft and mechanically weak but not fluid. If while still swelled the temperature be raised, depending on the gelatine used, to 30-40° C., it melts to a thick liquid, and on cooling it hardens, "sets," "gelatinizes," or "gels," again but slowly, not immediately on cool-

[4] See also Abney, "Photography with Emulsions," p. 102; Brothers, "Manual of Photography," p. 257; Burton and Pringle, "Processes of Pure Photography," p. 51.

ing. In the dry form it keeps indefinitely but when wet or dissolved in water it quickly putrifies, as it makes an excellent medium for the growth of molds and bacteria, and it then generally loses its setting power, becoming liquid or remaining liquid. Boiling in water steadily lowers the melting point till finally the setting power is destroyed. It absorbs chlorine, bromine and iodine readily, which is important in its photographic use, as it thus allows the more complete decomposition of the silver salt by the light, the removal of the halogen from the field of action preventing it from recombining with the silver. When boiled with silver nitrate the gelatine solution turns red and the silver salt is decomposed. Treatment of the swelled gelatine with quite a large number of substances, such as alum, chrom-alum, formalin, etc., raises the melting point or even renders it quite insoluble in water. It is not soluble in strong alcohol, and is precipitated from water solution by the addition of alcohol; even the swelled gelatine when immersed in alcohol loses water and shrinks down to a hard film.

9. **Silver Haloids.**—Of the compounds of the haloids, chlorine, bromine, and iodine, with silver, the bromide is the most important one in photographic work. Stas,[5] a famous Belgian chemist, studied the different forms in which it occurs and

[5] Stas, *Annal. de Chem. et Phys.*, 5th Ser., 3, 289 (1874).

how it may be changed from one to the other. Precipitated directly from water solutions, it is finely divided and a faint yellow, and quickly gathers into larger particles and settles to the bottom. If boiled for a long time in water out of the light the particles subdivide till it will remain suspended for a long time in water, and this finely divided form is exceedingly sensitive to light. It may be made also by precipitating dilute boiling silver nitrate solution with dilute boiling ammonium bromide solution. When precipitated from a solution containing a small quantity of one of many other substances, including gelatine, the particles of silver bromide carry down with them some of the foreign material—and this property has an important bearing on the manufacture of gelatine emulsions.

10. **Dry Plate Making.**—As an example of the preparation of a gelatino-bromide emulsion the following from Abney [6] will be described. Materials and their quantities are as follows:

1.	Pot. Iodide	0.3g in 3.5 cc water
2.	Pot. Bromide	8.7g in 40 cc water
3.	Nelson's No. 1 Photo Gelatine	2g.
4.	Silver Nitrate	11.4g in 15 cc water
5.	Heinrich's Gelatine	10g.
	Nelson's No. 1 Gelatine	6g.

The presence of both bromide and iodide increases the sensitiveness over that with either alone.

[6] Abney, "Treatise on Photography."

The use of the two kinds of gelatine is for the purpose of making the film hard enough when wet to stick sufficiently strongly to the glass, and yet of low enough melting point to absorb the solutions readily. Both lots of gelatine are washed with water to free them from dust and then allowed to swell in water. To the silver nitrate a drop of hydrochloric acid is added to make the emulsion acid. No. 3 Gelatine is melted by standing the drained swelled gelatine in a water bath at 50° C., and the silver nitrate added and well mixed. Then No. 2 Pot. Bromide is added slowly drop by drop, with constant agitation, of course in the dark room, till ¾ is added, when No. 1 Pot. Iodide is mixed with the remaining Pot. Bromide and the mixture added to the gelatine as before, drop by drop. This makes the precipitated haloid very finely divided, and the liquid with suspended precipitate is called an emulsion. It will be noted that the bromide and iodide are present in more than sufficient quantity to combine with all the silver nitrate, so that there is no free silver nitrate left to react with the gelatine. If a little of this emulsion is now examined by looking through it, it will be found to be ruby red. Place the flask in boiling water in the dark for 40 minutes. If plates be made from it at intervals, it will be found that the sensitiveness will be increasing steadily and the sil-

ver bromide particles increasing in size. At some time the sensitiveness will begin to decrease and the boiling should be stopped short of this point. It will be noted that part of the gelatine was reserved so that it would not be affected by the boiling. It is now warmed to melting and mixed with the emulsion, and the whole allowed to set.

In the emulsion besides the water, gelatine and silver haloids, there will be the following substances, KBr, KI, KNO_3, HCl (see reactions in Art. 5), and if these latter are removed the plate will be much more sensitive. To this end the jelly is now well broken up by squeezing through strong cloth, and washed and soaked and washed for hours. It is then well drained and is ready to coat the plates as soon as it is melted by warming. If a small quantity of alcohol is added before coating the plates it will increase the sensitiveness somewhat.

To make the layer of gelatine adhere to the glass surface through all the later operations it is necessary that the glass surface be absolutely clean. No one who has not actually attempted to thoroughly clean a surface realizes how difficult it is. All grease can be removed by a hot alkali solution, particularly if assisted by friction. Hot chromic acid or nitric acid will destroy all other organic substances and dissolve a good many inorganic. Wash thoroughly, finishing with distilled water. Many

workers finish by polishing with French chalk (finely divided calcium carbonate) on clean chamois leather or cloth, but the latter must be clean and must not be touched by the fingers on the part used for polishing. A layer of hardened gelatine or of albumen adheres to the glass very strongly, and the emulsion adheres to this layer strongly also so that most plates on the market are made this way when the cleaning does not need to be quite so thorough.

The plates are placed on a level surface and a measured quantity of the warm liquid emulsion poured on and spread to the corners with a glass rod in a very dim ruby light. The emulsion soon sets when it is best placed in a current of dry air in the dark till quite dry.

11. **Ammonia Modification.**—The above method is known technically as the boiling method, where the great sensitiveness is largely due to the prolonged heating during which the silver bromide goes into the sensitive form. Another method reaching about the same sensitiveness, is to add some ammonia at the point above when the boiling commenced, and to then let it stand for a day or so at room temperature. Some workers use one method, some the other. Repeated melting and solidifying of the finished emulsion also increases the sensitiveness.

12. **Centrifuge.**—The boiling of the emulsion as

above, deteriorates the gelatine used a great deal, and it is of advantage to get rid of this spoiled gelatine. This can be done following the boiling by whirling the liquid in a centrifugal machine, which is a cylindrical vessel arranged to be rotated rapidly about its axis. The heavy particles of silver bromide are by this means driven to the walls of the vessel and the fluid part may be poured out, carrying with it practically all the soluble salts and most of the old gelatine. The silver bromide is then added to fresh melted gelatine, and when thoroughly mixed is ready for coating the plates. Boiling the emulsion without any gelatine present gives but a poorly sensitive plate.

13. So far we have been concerned with the important outstanding photographic processes only. There are a great many others of more or less importance, with other light sensitive substances and supports. There are books filled with short terse descriptions of such processes literally by the hundred. We will need to consider a few of them later when we come to discuss methods of making positives. It should also be pointed out that except for some other difficulties in the handling of the flexible support, the films for film cameras are made like the dry plates are made. For some reason films have not been nearly as fast as the fastest plates, but they

have been fast enough for most work. Lately a faster film has been put on the market.

14. **Summary.**—To sum up again the reactions involved in the case of the making of a negative from a gelatine dry plate, thus in the light

$$AgBr = Ag + Br \text{ or } 2AgBr = Ag_2Br + Br$$

and we will leave the discussion of which occurs and of the theories generally till more of the facts are in hand. Then in the developer

$$2Ag_2Br + H_2O + R = 2Ag_2 + 2HBr + RO$$

or where there is a particle of the metallic silver due to the action of light, in the silver bromide particle,

$$2AgBr + H_2O + R = 2Ag + 2HBr + RO$$

where "R" is the developer which is in all cases a material which will take up oxygen. The function of the carbonate in the developer is partly to keep the solution from getting acid from the formation of the HBr. Then in the strong sodium hyposulphite (also called thiosulphate) solution

$$2AgBr + 3Na_2S_2O_3 = 2NaBr + Na_4Ag_2(S_2O_3)_3$$

and the complicated compound formed is soluble in water.

CHAPTER II

PROPERTIES OF THE GELATINE DRY PLATE—EXPOSURE AND DEVELOPMENT

15. Now that we have the description of the manufacture of gelatine dry plates, and have used them somewhat in the laboratory, the next step logically is the investigation of the properties of the plate. Here a qualitative investigation is not of much use, but the properties must be measured and the relation between the different experimental quantities expressed in mathematical form. For example we must answer, from the standpoint of experiment, such questions as,

> What is the relation between the amount of exposure and the density of the negative?
>
> How does the kind of developer and the time of development affect the density of the negative, and affect the relation between the densities of different parts of the negative?
>
> How should we measure and how express the speed of different plates?

and many more such questions. The answers are very valuable both in the experimental use of the

plates and the interpretation of what we get in the negative. In 1890 two Englishmen, Hurter and Driffield published[1] a description of some quantitative experimental work on the gelatine dry plate, which was the first of many papers by many workers. It was a splendid piece of work, and stirred up a vigorous controversy which has hardly died out yet. Their results have been checked many times and in different ways, and are now accepted as correct. Since they answer some of the questions which it is worth while to ask, a little time can be spent profitably over their paper.

16. **Hurter and Driffield** begin with a definition of a perfect negative—"when the amount of light transmitted through its different gradations is in inverse ratio to that which the corresponding parts of the original subject sent out." It is to be carefully noted that this does not say the same actual differences but only the same proportions; the actual differences may be either greater or less. That is if one subject sends out twice the light to the camera which another does, then it should be represented in the image by a place of twice the opacity.

[1] Hurter & Driffield, "Photochemical Investigations," *Jour. of Soc. Chem. Ind.* 9, 455 (1890); *Photo Miniature*, No. 56, where it is rewritten by Driffield; *Photo Miniature*, No. 66, application to the general problem of development. For a very complete treatment and many references see Sheppard & Mees, "Investigations on the Theory of the Photographic Process," Longmans, Green & Co., 1907.

The proportion and not the actual difference is the important matter.

Lambert 2nd Law

17. **Law of Absorption of Light.**—The next step is to investigate how the light absorbed by a translucent layer depends on the incident light and on the layer. This is important as it is the absorption of light by the sensitive film which makes possible its development into a negative, and the absorption of light by the negative which makes printing possible. Suppose we find by measurement that a certain film will absorb ¼ the light coming up to it, that is it transmits ¾. If we double the light coming up we will find that the fraction transmitted will remain the same, although the film is both absorbing and transmitting more than it did before. More measurements would show this to be the general rule, that the fraction transmitted is a constant independent of the illumination. In algebraic symbols

$$i = \frac{1}{m} I \qquad (1)$$

where I is the incident and i the transmitted light, and $1/m$ is the fraction transmitted, where m is a constant independent of I but dependent on the film used. Suppose now that two such layers be used, each layer will transmit ¾ of the light which gets to it, but the second layer only gets ¾ of the incident light, so that the fraction transmitted by the two films together will be ¾ × ¾ of the originally

incident light. For 3 layers it would be similarly $(3/4)^3$. Evidently if the fraction absorbed was different from 3/4, the same expression would still hold, that is if $1/m$ was transmitted by the first layer, then $(1/m)^n$ would be transmitted by n layers. That is, the more general form of equation 1 above is

$$\frac{i}{I} = (1/m)^n \quad \text{or} \quad \frac{I}{i} = (m)^n \tag{2}$$

and for convenience let us write $m = (10)^k$ which gives

$$\frac{I}{i} = \left((10)^k\right)^n = (10)^{kn} = (10)^d \tag{3}$$

The ratio $\frac{I}{i}$ is called the *opacity* because it is the amount of light which must fall upon the film to have unit quantity get through. The power kn, which is usually written d, depends only on the absorbing body and is called its *density*. In these terms the equation 3 may be written

$$O = 10^d \tag{4}$$ [2]

and this equation is the relation we set out to determine.

[2] For the student who has studied logarithms this may be written more conveniently thus:

$$\frac{i}{I} = (1/m)^n = m^{-n} = \epsilon^{-k_1 n}$$

whence $\log_e \frac{I}{i} = k_1 n$ and $\log_{10} \frac{I}{i} = \frac{1}{2.303}(k_1 n) = kn$

$$\text{or } \log_{10} O = kn = d$$

18. Photometer.—To measure the density of a photographic plate it is possible to separate the silver from a measured area of a negative, and from this get the density. But this method is very tedious and on account of the very small quantities of silver, is not accurate. It is better to measure the opacity of the plate and from it get the density by use

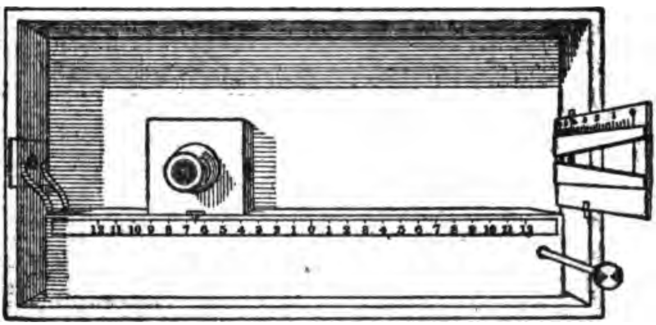


FIG. 1.

of equation 4 above. For this purpose Hurter and Driffield modified the ordinary bench photometer to make the apparatus pictured in the diagram, Fig. 1. Outside of the box at each end is placed a lamp, and the central box can be moved toward either end, thus getting more light from one lamp and less from the other. In addition to this the board with the wedge-shaped opening can be moved in and out, so changing the vertical length of the opening in that end of the box, and so varying the amount of light admitted

from that lamp. The position of each can be read on the scale attached. The arrangements inside the inner box is shown in Fig. 2. The vertical septum in the center of this inner box has a thin paper middle, in the center of which again is a spot which has been made more transparent with grease. The two inclined mirrors in the back of this box enable

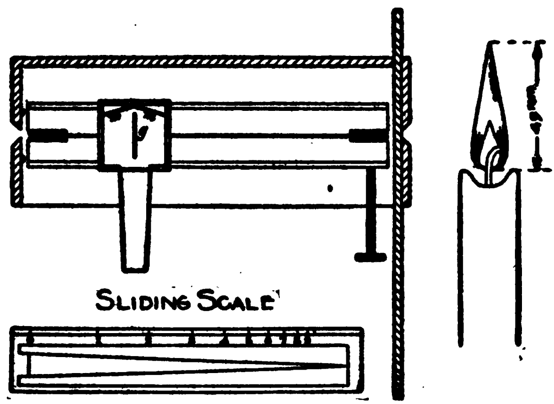


FIG. 2.

the observer to see both sides of this greased paper at once. If the illumination on the two sides of the grease spot is different, the spot looks lighter or darker than the surrounding paper. When the illumination on the two sides is equal the spot becomes invisible, and then the strength of the two sources will be directly as the squares of their distances from the grease spot. Then one light aperture is covered with the plate to be measured, the

small box is shifted till the grease spot becomes invisible again; from these two settings I/i is easily calculated,[8] and from that the density. To determine how much dependence could be placed on the instrument, they determined the density of known solutions of India ink, and the determined and known values agree to about one per cent.

TABLE I

India Ink added to 100 cc Water	Density calculated	Density measured
5 cc	0.240	0.240
10	0.480	0.500
15	0.720	0.750
20	0.960	0.950
25	1.20	1.245
30	1.44	1.44
35	1.68	1.665
40	1.92	1.885

This is consequently all that should be expected in its regular use. The table showing the measurements is given above.

19. **Fog.**—Obviously if one wants the density of the silver forming the negative image it will not do to include with this the density of the gelatine and of the glass plate, for both these absorb some light. Also there is always some chemical fog, that is silver reduced which is not due to the action of the light which formed the negative. To get the

[8] See appendix on photometer, p. 280.

density due entirely to the action of the light it is necessary to allow for these other densities, and they made a practice of leaving a small part of the plate unexposed, measuring the light absorbed by it, and subtracting this amount from the density of the rest of the plate to get the density due to light. For example to test the effect of time of development, they exposed a plate except a narrow strip along one edge, then cut up the plate at right angles to this unexposed strip, and developed each of these strips a different length of time. The following table gives the actual measurements.

TABLE 2

Time of development, minutes	2.5	5.	7.5	10.	15.	20.
Density exposed plate	.670	.965	1.245	1.420	1.755	1.945
Density unexposed plate	.200	.345	.415	.505	.575	.710
Density due to light	.470	.620	.830	.915	1.180	1.235
Percent developed	38.	50.2	67.2	74.1	95.5	100.

Note that the density of the negative grows with time of development, but the density due to light reaches a maximum in this case in about 15 minutes; also note what a large proportion the fog is of the total density, and that it continues to grow steadily even after the light image has reached its maximum. The first fog figure (.200) is the density almost exactly of the glass plate and the gelatine, and this should be subtracted from the later fog

readings to get the true fog. At small values the fog is approximately uniform all over the plate and consequently will not affect the printing qualities except to require longer to make the printing exposure.

20. **Ferrous Oxalate.**—All the alkaline developers have this undesirable property of producing a lot of fog, which is especially undesirable in this kind of work. The ferrous oxalate developer which works in acid solution produces very little fog, even an hour's development of an unexposed plate giving hardly enough fog to measure. The developer is made by mixing strong solutions of ferrous sulphate and potassium oxalate. These react to give ferrous oxalate, thus:

$$FeSO_4 + K_2C_2O_4 = FeC_2O_4 + K_2SO_4$$

which is not soluble in water but is soluble in an excess of the potassium oxalate solution. When in contact with exposed silver bromide, they react thus:

$$K_2C_2O_4 + 2FeC_2O_4 + 2AgBr = Fe_2(C_2O_4)_3 + 2KBr + 2Ag$$

that is the ferrous salt changes over to ferric, metallic silver is formed, while the amount of acid present does not change. Unfortunately the solution absorbs oxygen from the air fairly rapidly, and the ferrous salt not being very soluble, soon precipitates, but does little harm when it does precipitate and

merely calls for a little care in not using the developer too long. On account of its non-fogging property they used it for most of the quantitative work.

21. **Growth of Density.**—They exposed one-half the plate to light and then cut it up so as to include a part unexposed and a part exposed on each piece, developed in the oxalate developer, fixed and washed it. After drying the density was measured in the photometer, subtracting the fog to get the density due to the action of the light. The first step was to determine the way in which the density grows in the developer. For this purpose different pieces were developed for different lengths of time, and with developer differing in the amount of the two constituents, of water or of potassium bromide. The resulting densities are given in the following table:

TABLE 3

Time			Density exclusive of fog.				
Mins.	I	II	III	IV	V	Mean	Calculated
5	.365	.350	.....	....	.215	.332	.290
10	.525	.460	.....	....	.305	.462	.464
15	.615	.550	.795	.570	.410	.569	.568
20	.615	.575	.....	....	.420	.582	.628
25	.700	.650	.....	....	....	.660	.665
30	.700	.660	.860	.670	.450	.645	.687
45	....	....	1.000	.715	.515	.715	.713
60	....	....	.....	.740	....	.740	.719

This table shows that, as in the previous table, the densities grow rapidly at first, then more slowly, finally reaching a maximum value. The rate of

growth is quite different in the different cases, I-V, and besides depending on the developer depends on the gelatine of which the plate is made and on the age of the plate. By a method of guess and try they were led to the equation

$$d = D\,(1 - a^t) \tag{5}$$

where d is the density at the time t, D is the final density and a is a fraction chosen to suit the case.

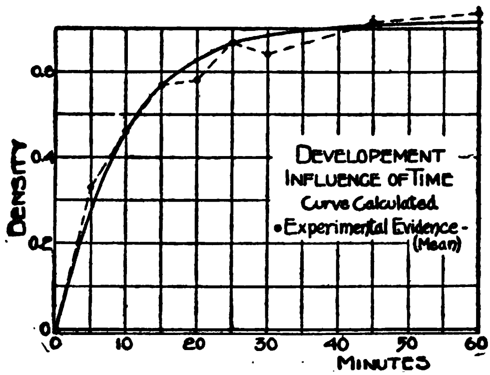


FIG. 3.

This equation enabled them to calculate the density at any time during the progress of development. This is well shown by the agreement of the column mean and calculated of Table 3, this data is plotted in Fig. 3, where the curve is the calculated points and the experimental points are the dots.

22. **Constant Density Ratios.**—This formula has some very interesting consequences, for example when t is large, a being a fraction, a^t becomes small,

and when t is sufficiently large, a^t becomes small enough in comparison with 1 to be neglected, that is d becomes the same as D. That is to say the formula shows that the density will reach a maximum which is in agreement with experiment. Or suppose we had two places of different exposure on the same plate where the final densities will be D_1 and D_2, then the densities at any time t will be given by

$$d_1 = D_1 (1 - a^t) \text{ and } d_2 = D_2 (1 - a^t)$$

where the time from the start of development is the same in both cases, namely t, and a is the same all over the same plate. If we divide one of these equations by the other, the bracketed part divides out, and we have,

$$\frac{d_1}{d_2} = \frac{D_1}{D_2}. \qquad (5a)$$

That is, the ratio of the densities at any time t during development is the ratio of the final densities, and since this is true for any time it is true for all time during development. That is, the ratio of the densities at the two places is always the same no matter when you stop development. This does not say that the actual densities do not change, they grow greater and their difference grows greater, that is, contrast grows greater during development. But nevertheless one place is always the same proportion denser than the other. They confirmed this result, as it is very important, by a lot of experi-

ments, using plates from different makers and many other developers than the oxalate. Nor did changing the developer during the progress of development affect this result.

23. **Application in Practice.**—It follows that the ratios are independent of any ordinary treatment during development. Of course covering only part of the plate with the developer will upset this rule, or warming it locally, for example, with the fingers. It is of course a series of densities which make a negative and it is the ratios between them and not their absolute values which are most important in the negative and in the print. It is fortunate that it is not a matter of special skill and manipulation to keep the ratios true to the light values making the negative and therefore true to the subject. A correctly exposed negative fills their definition of a perfect negative almost entirely independent of the process of development. All that can be accomplished by ordinary manipulation during development is to fix the density at one point in the negative and hence to fix it at all other points.

Any attempt by manipulation during development to bring out one set of detail and to subordinate another is useless. Moreover if the plate was not correctly exposed it can only be very imperfectly remedied during development. All there is any need to do is to interrupt the progress of devel-

opment when the highest and lowest densities are not too far apart in actual value for the print to show their difference, nor so close together that they do not use a good deal of the range of densities of the print. It is for this reason that you have been urged to control the development of your plates by following the time for which they are in the developer. By choosing the time of development to suit the developer used and the brand of plate, and then making the exposure such as will give a suitable density for printing, one will get the best pictures. But where one guesses at the exposure and then tries to adjust the treatment in the developer so as to correct errors of exposure, there will be two things to blame the failures on, and no real guide as to which one was actually wrong. But by choosing and adhering to a suitable time of development, one will be sure that the errors are in the exposure, and so by watching the successes and failures learn to make correct exposures. In fact tank development is the logical thing.

24. **Intensification.**—The next experiment was to test the effect of intensification, and the same rule of constant density ratios was found here. The increase is proportional to the density before intensification. An example is given in Table 4. The plate was exposed, developed with ferrous oxalate, the densities measured, and after-

wards intensified and the densities measured again.

TABLE 4

Exposure	Before Intensific. Density D_1	Ratio	After Intensific. Density D_2	Ratio	D_1/D_2
10.0	.31	1.0	.60	1.0	1.93
14.0	.50	1.61	.91	1.5	1.82
20.5	.67	2.16	1.30	2.16	1.94
29.3	.86	2.77	1.71	2.85	1.98
41.9	1.03	3.32	2.15	3.5	2.08
60.0	1.30	4.19	2.56	4.2	1.96
				Mean	1.95

It is to be noted that the two columns of "ratios" are similar line for line, and also the factor by which the density has been changed by intensification is the same for all the different densities, within the error of experiment. Both facts show that the density ratios are not changed by this method of intensification, which is then merely another way of continuing the process of development. Many other intensifiers, however, do change the ratios, (Art. 64), as also do most reducers (Art. 68).

25. **Characteristic Curve.**—Having answered these questions with respect to developers and development, the next step was to investigate the effect of exposure on the production of density. For this purpose it is advisable to choose some unit in which to express the exposure, and they used the light from a standard candle burning for one second at one meter distant from the plate. This they

call the candle-meter-second, and it has been very generally used since their time. Using this unit to measure the exposure given, they gave a series of exposures increasing by factors of two to different parts of a plate, by uncovering one particular part of the plate at one time; and developed it in ferrous oxalate.

TABLE 5

Exposure	Density	Difference	Exposure	Density	Difference
0.625	.045	.....	80	1.110	.255
1.25	.055	0.010	160	1.270	.260
2.50	.085	0.030	320	1.555	.285
5.00	.175	0.090	640	1.885	.330
10.0	.250	0.075	1280	2.088	.203
20.0	.460	0.210	2560	2.262	.174
40.0	.755	0.295	5120	2.352	.090

It will be seen that every time the exposure is doubled the density increases, at first slowly, then considerably and (disregarding errors of experiment) from 40 C. M. S. exposure up to 1280, every time the exposure is doubled nearly an equal addition of density is the result, the addition to the density being on an average 0.266, but after an exposure of 1280 further doubling produces less and less increase in density. The first few densities are too small to admit of accurate measuring.

This series of results is represented graphically in Fig. 4, exposures horizontally and densities vertically; from this diagram it will be seen at

once how rapidly densities grow at first as exposure is increased, and how slowly at last the densities tend toward a limit.

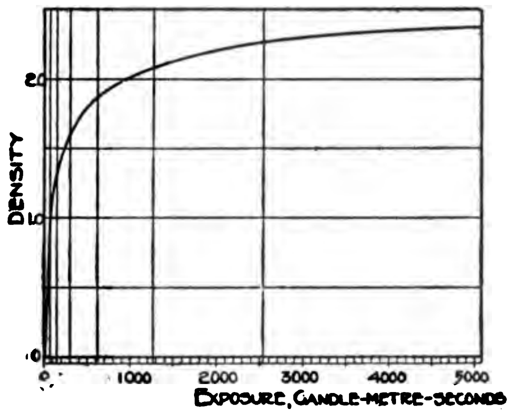


FIG. 4.

There is something more to be learned from a series of exposures running to still higher values, and they give another experiment very similar to the last.

TABLE 6

Exposure	Density	Difference	Exposure	Density	Difference
1	.060	....	1024	2.985	0.450
2	.160	.100	2048	3.115	0.130
4	.340	.180	4096	3.280	0.165
8	.500	.160	8192	3.405	0.125
16	.715	.215	16384	3.508	+0.103
32	.940	.225	32768	3.474	−0.034
64	1.345	.405	65536	3.280	−0.194
128	1.875	.530	131072	3.128	−0.162
256	2.290	.415	262144	2.920	−0.208
512	2.535	.245	524288	2.464	−0.456

Note that toward the end of this series of exposures the addition of more exposure actually lessens the density on development. To represent this diagrammatically as in the previous case would require a diagram impracticably large and would not give information of any value. But if the method of plotting be changed it can be made into by all means the best way of treating this data. The change required is simple, instead of giving equal distances horizontally to equal amounts of exposure, give equal distances to equal multiples of exposure. That is in the case here each multiplication by 2 moves the point an equal distance to the right. The result of this is to crowd closer together relatively the points at the long exposure end of the list. This will give us the curve, Fig. 5, which is called the Characteristic Curve.[4]

The curve consists of four distinct branches. The first curved portion, convex downward, is called the period of underexposure. The straight middle portion, the most important part, is called the period of correct exposure. The part following this and bending to the right, concave downward, including up to the maximum density, is called the period of

[4] The student who has studied logarithms will notice that we are here plotting the logarithms of the exposure on the horizontal axis while plotting the densities linearly. And therefore for the straight line portion of the curve (log. E—log. i) is proportional to the density.

overexposure. And fourth, the final bending down part is called the period of reversal. We will consider the second part in detail first.

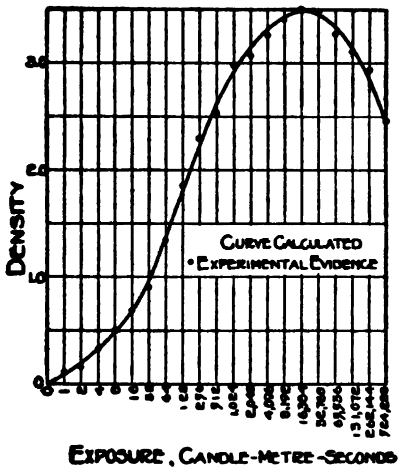


FIG. 5.

26. Period of Correct Exposure.—In the diagram, ab is a straight line within the error of ex- p.38
periment. Let x be any point on it, and draw xy at right angles to cy. Then wherever x may be on ab, the triangle xyz remains similar, that is

$$\gamma\ (yz) = xy$$

where γ (gamma) keeps the same value, being the number of times that one side is greater than the other.

Let us examine further the way we have plotted the exposure. If E is the exposure, we may put

$$E = 10^v$$

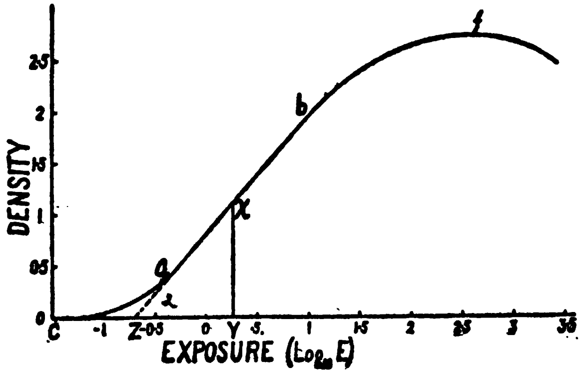


FIG. 6.

where v is a suitable number and then multiplying E by a factor means making an addition to V. For example if we multiply by 10, then

$$10E = 10^v \times 10 = 10^{v+1}$$

Or if we multiply by any number X, we can always write

$$X = 10^n$$

where n is a suitable number, and therefore

$$XE = 10^v \times 10^n = 10^{v+n}$$

So that we really plot the index v of some suitable number such as 10. In the actual case above plotted

the suitable number was 2 and when we had chosen a distance to represent unit exposure, we plotted the index in the series 1, 2^1, 2^2, 2^3, 2^4, etc.

If we have been careful to make our plotting of the above diagram suitably, we may write

$$E = 10^{ey}$$

and let us choose "i" a number such that

$$i = 10^{ex}$$

Dividing one by the other, we get

$$\frac{E}{i} = \frac{10^{ey}}{10^{ex}} = 10^{(ey-ex)} = 10^{zy}$$

But in the discussion above it is shown that

$$zy = xy/\gamma = d/\gamma$$

Whence $$E/i = 10^{d}/_{\gamma}$$

27. **Perfect Negative.**—Experiment shows that as development proceeds the curve ab swings up about the point z as center, that is, becoming steadily steeper. Let the amount of development be so chosen that the γ in our above expressions is unity, that is, the slope of the line ab will have to be 45°. For this special case, then,

$$E/i = 10^{d}$$

It was shown above in Art. 17 that

$$O = 10^{d}$$

and therefore

$$E/i = O \qquad (6)^{5}$$

For any particular curve the value of i is a constant, and therefore the opacity (O) is directly proportional to the exposure (E). The amount of light transmitted is inversely proportional to the opacity so that this statement becomes, the amount of light transmitted is inversely proportional to the exposure, which is the definition, Art. 16, that Hurter and Driffield give of a perfect negative.

Hence it is possible to make such a perfect negative by filling two conditions: (1) the exposure of every portion of the plate must be such as to bring it onto the straight line portion of the characteristic curve, and (2) the time of development must be such that γ will be unity.

28. Period of Underexposure.—This includes the initial bend of the characteristic curve lying be-

[5] For the more advanced student this may be more conveniently written thus:

$$\tan \alpha = \frac{d}{\log E - \log i} = \gamma$$

where α is the angle between the straight part and the E axis.

For the case of $\gamma = 1$, $\qquad d = \log \frac{E}{i}$

But $d = \log O$ (Art. 19) $\qquad \therefore O = \frac{E}{i}$

and since i is a constant for all the straight part

$$O : E$$

or the opacity is proportional to the exposure.

tween the letters c and a in Fig. 6. The slope of any part here is always less than that of the part ab, so that for the same time of development the densities will be much less, and also the density differences between any two points, that is, the contrast will be less, and the negative will in general be thin and flat. Not only that but the contrasts will not be graded as they are in the subject, but will be relatively greater than they should be in the longer exposed parts, and detail will be lacking in the shadows. The print will not be true to the subject.

Note carefully that the above is true for the same time of development or in better words for the same development factor (gamma). Many texts and workers say that "underexposure gives contrasty negatives," which is not strictly the case. It should read that "the longer development usually given underexposures leads to contrasty negatives." When the progress of development of a negative is followed by looking at it or through it, the watcher stops development when the negative has reached the opaqueness to which he is accustomed. The result is that the short exposure negative is developed a long time, and as contrast—density difference—grows with development, this results in a contrasty negative. On the other hand a liberally exposed negative grows black quickly all over in

the developer and is removed before the contrast has had time to grow great, resulting in a soft or even flat negative. For the same subject and lighting the difference in the contrasts in the two cases is produced in the developer, not in the exposure.

Exposures falling on the part of the curve ca are so small as hardly to give printing density even on prolonged development. Such a negative may be intensified, so continuing the process of development, and thus be built up to good printing density. The contrast will however become very great, giving hard, black and white prints which are quite untrue to the subject.

There are many negatives which for the greater part of the subject are satisfactorily exposed but for some dark objects or weakly lighted ones are given such exposures as to fall on this initial part of the curve. In the print these objects do not appear as they should but are weak or even lacking in detail. The old maxim of "expose for the shadows and the high-lights will take care of themselves" is worth remembering.

29. **Period of Overexposure.**—This includes the upper curved portion as far as the highest point, that is from b to f in Fig. 6. As in the part ca, the slope here is always less than that of ab, so that, though the densities may be much greater, the contrasts are less and the negative is flat. The nega-

tive is so dense as to require a long exposure for printing, so that it is hardly feasible to prolong development or to intensify to increase contrast. In skillful hands reduction offers a means of improving the printing qualities. Plates the main part of whose exposures fall on this part of the curve, that is true overexposure, occur less often than true underexposure, since the regular practice aims to give an exposure lying close to the lower limits of correct exposure.

30. **Period of Reversal.**—This includes the curve from f to the right in Fig. 6. Here increase of exposure actually decreases the density obtained on development. It is possible with care to get a positive, a flat poor one, but the exposures have to be very great indeed, so great that one never meets with such reversal in ordinary work. It is of interest largely to the investigator who is working to develop a satisfactory theory of the latent image.

It is difficult to overestimate the importance of the characteristic curve for a correct understanding of photographic work.

It summarizes in a handy, usable way the most important properties of the dry plate. The previous paragraphs have indicated some of these and there are a number yet to be discussed.

31. **Dependence of Slope on Development.**—The method of obtaining the characteristic curve, see

Art. 25, was to expose a plate for known different times on different spots, and then develop the whole plate alike. Curves can be obtained in this way where the only difference in the treatment of the plate is in different times of development. Fig. 7 is a typical case of two such curves where the developer used contained no soluble bromide. The

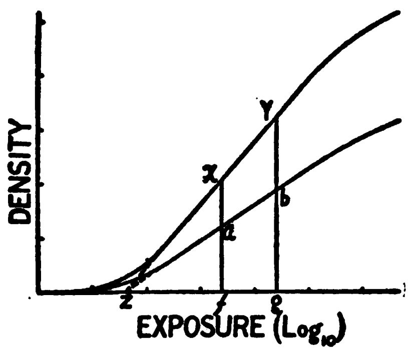


FIG. 7.

upper and steeper curve is for the longer development. The straight portions when extended meet in the point z which lies on or near the horizontal axis. Hence as development proceeds the straight part really rotates about this point. If the development be very prolonged the curve reaches a maximum slope since development finally ceases, see Art. 19, and this maximum slope or value of γ (called γ_∞) varies with different kinds of plates.

These observations are in agreement with the

results given in Art. 21 and could have been predicted from them. Equation 5a was

$$\frac{d_1}{d_2} = \frac{D_1}{D_2}$$

That is, as development proceeds the different densities always keep the same proportion. In Fig. 7 from similar triangles

$$\frac{af}{bg} = \frac{xf}{yg}$$

which is the same statement as Equation 5a.

The presence of soluble bromide, potassium bromide usually, in the developer shifts the point z below the axis. This means suppressing the lower densities, and in the case of plates there appears no compensating advantage, so that plate developers free of bromide are to be preferred.

32. **Development Factor.**—In Art. 26 it was shown that

$$xy = \gamma . yz$$

or

$$\gamma = \frac{xy}{yz}$$

And therefore the value of γ (gamma) depends on the angle between these two lines, or in other words on the slope of ab (Fig. 6). From the preceding discussion, Art. 31, it will be evident that the value of γ is a measure of the amount of development, and it is hence called the development factor. For a true picture the lights and shades must be

proportional to those in the subject, which requires a "perfect negative," see Art. 27, for which γ must be unity, and the slope of the line ab therefore 45°. If the development is carried beyond this, γ becomes greater than unity and the contrasts will be exaggerated. If development is stopped short of this, γ will be less than unity, and the contrasts will be softened. In Art. 86 are discussed the reasons which may lead to the choice of a development factor different from unity.

The amount of development, that is the development factor, γ, depends on a number of things. (a) The developer, meaning by this the kind and amount of every constituent. By ordinary care in the making up of the solutions this may be easily kept sufficiently constant to be relied upon. The choice of a developer is discussed in Art. 38. (b) The time of development, which is readily controlled. (c) The temperature, which may be controlled or different temperatures may be readily allowed for by changing the time of development. This will require reading the temperature and knowing the effect of temperature on the rate of development. See Art. 33. (d) The dry plate. In order that a particular brand of plates may give uniform results, the time of development for γ equal one must not vary materially, and the good plate makers' efforts are directed to maintaining this constant in different

batches. With different brands of plates this time of development is very different. The careful user of plates will welcome the time when each box of plates will contain a statement of the plate speed, a formula for a good developer, and a table of the temperatures and the times of development for obtaining γ equal one with this developer. (e) The age of the plate. In moderately new plates which have been kept dry and cool, and away from active gases, the age is not a material factor. But under other circumstances the age of the plate may introduce as much as a factor of three in the time of development for γ equal one.[6]

33. **Practical Control of the Amount of Development (Contrast).**—In the dark room, two of the factors in the above list offer difficulty, that is the temperature and the plate. To manage all of them and so control the contrast, there are several distinct procedures possible.

(a) Use always the same brand of plate so that it may be assumed that its development speed remains constant. This will hold quite satisfactorily for plates of the same batch of emulsion but the variation of different batches may have to be compensated for by changing the time of development; the probabilities are, however, that in ordinary picture taking it will require careful attention to notice the

[6] Sheppard & Mees, "Investigations," p. 56.

difference. Develop all exposures for a fixed time at a fixed temperature. Determine the time of development by exposing several plates for the same time to the same subject, and develop them for different times at the fixed temperature. From the print select the development time for the plate which has the contrast you like. The temperature may be readily controlled by using a large tank of water and adjusting its temperature as necessary by the addition of hot or cold water. The size of the tank will prevent its temperature changing quickly. The plates may be developed in metal trays floated in the tank, or in a closed box immersed in the tank. This general method has been used in considerable experimental work.

(b) Again assume the plate a constant factor by using one brand. Make up the developer from water and concentrated solutions, all of which have stood in the room long enough to have acquired its temperature. Read the temperature of the mixed developer and by means of a development time-temperature table determine the time. In this Art. a list of temperature coefficients for some of the ordinary developing agents is given. The temperature coefficient is the factor by which the speed of development changes for a rise of 10° C.[7] In

[7] For 1° C. the coefficient would be the antilog of 1/10 the log of the coefficient for 10° C.

another column is given the coefficient for 1° C. If a suitable time giving the contrast desired has been determined, as in method (a) above, the time for each degree above (or below) the temperature used in the test may be found by successive multiplication (or division) by the one degree coefficient. In this way can be built up a table giving the times of development for the various temperatures likely to occur. This is probably the most usable method for tank development and for plates which are sensitive to the dark room light and must be developed entirely in the dark.[8] It should be observed however that these coefficients are dependent somewhat on the plate used [9] and are not constant over a wide range of temperature, but when used as above the errors will not ordinarily be troublesome.

(c) **The Watkins Factorial System.**[10]—Watkins found by experiment that the time taken for the first detail of the high light of a negative to appear when immersed in the developer, was not dependent on the exposure if it was within the usual limits, but dependent only on the speed of development.

[8] Wratten & Mees, "Development by Time," *British Journal*, 57, 376 (1910); Watkins' *Photography*, page 105, D. Van Nostrand Co., N. Y. (1911). This is one of the best texts now published.

[9] See also appendix, page 219, on development.

[10] Watkins' *Manual*, Burke and James, Chicago; Watkins' *Photography*, D. Van Nostrand Co., New York (1911); Mees and Wratten, *Brit. Jour. of Photo.*, vol. 54, p. 560 (1907).

In consequence this time is a measure of the speed of development, and one only needs to continue development for a definite multiple of this time to reach the same contrast in all cases. This multiple, called the "Watkins Factor," is not dependent on the plate used, nor on the temperature of development, nor within moderate limits on the concentration of the developer, but is dependent on the developing agent used and on the contrast desired in the negative. See the Manual, Exp. 6, for detailed directions. Below is a list of factors for some of the common developing agents where the contrast reached is 0.9 gamma.

TABLE 7

Developing agent	Watkins Factor for = 0.9	Temp. coeff. for 10° C	Temp. coeff. for 1° C
Pyro, 8g/L, no bromide.....	9	1.5	1.041
Metol Hydro as in Manual...	10	1.9	1.066
Hydrochinon with Bromide	5	2.2	1.082
Ferrous oxalate	..	1.7	1.055
Rodinal.......	40	1.9	1.066

34. **Contrast.**—Contrast is defined as the actual *difference* in density between the two points being compared on the negative, or

$$d_2 - d_1 = \text{contrast}$$

It is not concerned with the magnitude of the density, so that a negative in general very dense may have very small contrast if it has small differences in densities between the various points. In a negative which has been exposed so as to fall within the period of correct exposure, contrast depends on three things:

(a) Brightness differences in the image allowed to fall on the plate. In studio work this is under ready control, but in outdoor work the only control is by choice of time of day or of character of day. (b) Development factor. As development proceeds the densities increase proportionally so that the differences increase, or contrast grows with the progress of development. When prolonged, development slows up or stops and maximum contrast from this factor has been obtained. (c) Fog. It is the result of the reduction by the developer of the silver bromide which has not been affected by the light. Obviously the most fog will be produced where there is the most unacted on silver bromide, that is, in the thin parts of the negative. Its effect will always be to reduce the contrast and it may be a very material factor in moderately long development.

Maximum contrast is obtained by choosing a plate having a large possible development factor (process plates), exposing it to a brilliantly lighted

subject, and developing it for a long time in a developer which produces as little fog as possible. This contrast may be increased greatly by intensification.

35. **Thickness of Film.**—The effect of the thickness of the film on the glass plate is shown by the curves of Fig. 8. For a given exposure and

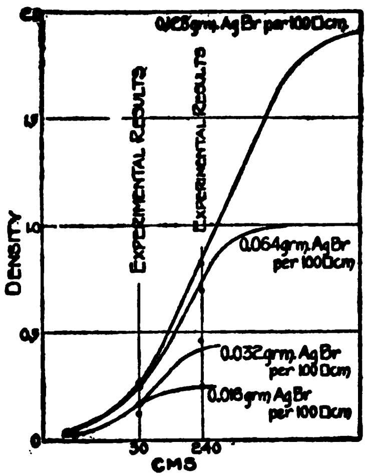


FIG. 8.

amount of development, the density depends on the thickness of the film; in general the thicker the film the greater the density. The thinner coated plates have a much shorter straight part to the curve, that is, the period of correct exposure (called latitude) is much shorter, the exposures have to be more accurately timed to fall within it, and it may be even

incapable of rendering strong contrasts. The thinner coated plate is however a trifle faster, but the greater speed is obtained at too great a cost, much the better all round plate is the one with a generous amount of the silver salt per unit of area.

36. **Like Negatives from Different Exposures (Latitude).**—Suppose a number of negatives be made giving each a different exposure but yet such a one that it falls completely within the period of correct exposure. All are developed for the same length of time in the same developer. This will make all the plates fall on the same characteristic curve. The longer exposure given a plate merely multiplies the exposure everywhere on the plate without affecting the proportion between the various spots on the plate. That is, the amount of light coming from the brightest object will be the same multiple of that from the weakest object for each of the different plates. In the regular characteristic curve diagram equal multiples of exposure are plotted as equal horizontal shifts. Hence in the diagram Fig. 9, if xy are the limits of exposure for one plate, x′y′ will be for the other, and the distances xy and x′y′ will be alike. Then the distances bc and b′c′ will also be equal. That is, the differences in the densities (contrast) in the two plates are alike and they will give identical prints. One plate will be denser than the other, a′x′ being greater than ax,

and will require a longer printing exposure, but if the printing exposures are made such that the same amount of light gets through to the paper in the two cases and the papers are developed alike, the resulting prints will be identical.[11]

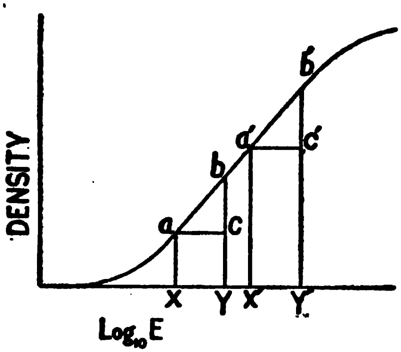


FIG. 9.

This result is very important, as it means that it makes no difference in the print where the plate exposure lies within the period of correct exposure. The latitude of good plates is large, about a factor of 60. Outdoors, in sunlight, the sky will be about 30 times as bright as a piece of black velvet.[12] An interior picture including a window will exceed this considerably. On the other hand, subjects which do not include any brightly lighted white articles

[11] See series of prints published by F. D. Todd in *Photo Beacon* 16,300, Nov., 1904, where the plate exposure was varied from 1 to 16 and the prints are indistinguishable.

[12] C. E. K. Mees, *Wilson's Photographic Magazine*, Dec., 1913.

or very dark ones will be considerably less than this which gives considerable margin, a factor of at least 4, often more than 10, in estimating exposures within which the prints will be the same.

37. **Organic dry plate developers** are very much alike. The active material is some good reducing substance like pyrogallic acid, metol, hydrochinon, glycin, amidol, and so on for several hundred. Too strong a reducing substance will attack the whole of the silver salt, so that the substance used has to be of a reducing power such as to distinguish between the two states of the silver salt. Experiment has shown that there is nothing gained in having it present in greater proportion than a few grams per liter, for example about 4g per L is the maximum useful amount of pyro. A few of the developing agents work without the simultaneous presence of an alkali (amidol, dianol). Most organic developing agents require the presence of some alkaline substance to cause it to become active. It is possible that the hydrobromic acid liberated by the reaction prevents further reduction unless it is neutralized. Almost any alkaline material will serve, the usual ones being the carbonates or hydrates of potassium or sodium. The carbonates are to be preferred, as they are not as destructive of everything they get on including the skin. The speed with which the developer acts depends more on the

concentration of the alkaline substance than on that of the reducing agent itself.

As a rule most developing agents stain a little, some stain vigorously, and the sulphite has the property of holding up this staining habit, but most developers will work well without it. Unfortunately the sulphite adds strongly to the fogging properties, but this fogging may be prevented for the ordinary times of development by the presence of a definite amount of potassium bromide. This latter is called the restrainer, as it also slows up the action of the developer on the latent image. In a general way the velocity of development depends on the concentration of the developer, and halving the concentration, that is, doubling the volume by adding water, will double the time necessary for the same contrast, that is for the same development factor. In the use of the tank one can calculate the time required as inversely as the dilution, though it is only approximately true and will not hold over wide ranges.

38. **The choice of a developer** will turn upon several factors. It should be cheap, easily compounded, keep well when made up, produce very little fog, and not stain the gelatine, paper, or fingers. There should be sufficient of the active agent present to complete the development of a dense plate without the solution becoming exhausted. The alkali should be adjusted so that the time required

is a convenient one, three to seven minutes,—so that the time required for immersing the plate in the developer, or for changing it to the hypo will not be a material fraction of the time of development. If sulphite is present it should be there in sufficient quantity to hold up the staining for the time required for the development. In paper developers the presence of the sulphite will require the presence of bromide to hold up the sulphite fog which would gray the whites.[18] The effect of the bromide on the lower gradations makes it advisable to omit it from the plate developers. Developers for use in tanks must be chosen with special reference to their resistance to air oxidation and to freedom from staining habits. In all cases the smaller the fogging property the better. The developer advised by the maker of the plates or paper, while not necessarily the best in each case, may be depended on to give good results.

39. **Estimation of Exposure.**—Exposure is defined as the ratio between the amount of light and the area on which it falls, or in other words the amount of light per square centimeter. It cannot be too strongly emphasized that to make a satisfactory negative the plate must be correctly exposed, that is all the different amounts of light from the

[18] Mees & Piper, "Fogging Power of Developers," *British Journal*, 58, 491 (1911).

different parts of the subject must expose the corresponding part of the plate so as to fall within the latitude. The latitude includes the exposures falling on the straight part of the characteristic curve, and a limited amount of the curved parts may be included without noticeable loss. This leaves a good margin with almost all subjects and most plates. See Art. 36. The different factors affecting the exposures are: (a) the time for which the camera remains open, (b) the stop used, (c) the speed of the plate, (d) the character of the subject, and (e) the lighting. The first three, time, stop, and plate speed, practically are easily managed and fairly constant factors, requiring only a little experience to make their management certain. The subject is often deceptive and uncertain, but judgment of the lighting is of all the most continuous and persistent difficulty. All these factors are discussed in detail below.

40. **Shutters.**—The time for which the camera remains open depends usually on the mechanism called the shutter. When used merely as a means of opening and closing the lens ("time" and "bulb" settings) they are usually reliable, though they will occasionally fail to open or close as expected, so that some experienced workers refuse to use any save the very simplest, most reliable types.

There are a number of different types of shut-

ters, drop-curtain, revolving sector, roller-blind, diaphragm, all of which are placed close to the lens either in front, behind or between the components. Undoubtedly the most consistent, accurate, and efficient are the roller-blind, focal-plane shutters. They can be fitted to almost any camera, but are expensive, somewhat bulky, and less simple to use. In these a roller blind, with a slit of variable width across it, passes just in front of the plate at an adjustable speed. They are the only fully dependable shutters for speeds above 1/50 second.

The great majority of cameras are fitted with between-the-lens shutters, in which the iris diaphragm opens and shuts, or separate blades move to open and close the lens.

There are several ways in which shutters give trouble. The most difficult to deal with is lack of consistency. They do not always give the same duration of opening when set in the same way. Most shutters now use the escape of air from a partly closed cylinder as the means to control the time. To obtain rapid motion without jarring the camera, the moving parts have to be very light and the springs weak, under which circumstances friction becomes a very difficult thing to keep constant.

The time markings are usually intended to mean the time between the first and last appearance of opening. With a moving subject the duration of

exposure must be short enough that the blurring produced in the picture will be barely visible. Very few shutters are reasonably true to the times marked. The highest speeds seldom exceed 1/35 second, that is the settings marked 1/25, 1/50, 1/100, all give 1/20 to 1/35 second. The slower speeds can be adjusted to offset the aging of the spring and the wear on the bearings but without any great effect on the higher speeds.

With this way of marking the times, no account is taken of the fact that the shutter requires time to open and time to close. For speeds of one second the proportion of the time spent in opening and closing is small, so that the amount of light getting to the plate is almost as great as if the time spent in opening and closing was zero, and the efficiency is therefore nearly unity. But as one goes to the higher speeds the proportion of the time spent in opening and closing becomes greater, so that the efficiency may drop as low as 25%. In many shutters the higher speeds are limited by the time required for opening and closing, and the lens is at full aperture only a very small fraction of the total time. One can conclude that the reliability, the accuracy and the efficiency are none too good and that they are often unsuspected but prolific sources of trouble.

The complete testing of a shutter for ac-

curacy and efficiency is a complicated matter. Sufficient information for ordinary use may be obtained by exposing a plate in sections by each time covering the rest of the plate with black paper. Use a uniform, evenly lighted subject—a white brick wall for instance—and change the shutter setting for each section, at the same time changing the stop so as to offset the change in time. On development all the sections should be uniform in density. If they are not the trouble is almost certainly with the shutter, as the diaphragm can usually be depended on. By measuring the density in the photometer one can determine how much the shutter is wrong in the matter at least which concerns the user most, namely the total amount of light admitted.

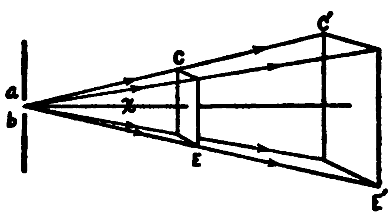


FIG. 10.

41. **The Stop.**—The system of numbering applied to stops requires a very detailed explanation.

In the figure let ab represent the diaphragm in the lens through which the light passes to the plate

CE. Consider a single point in the opening ab; from it the light will spread out in a cone to cover CE. The amount of light falling on a square centimeter of CE will evidently depend on the distance of CE from ab; the greater the distance the greater the area over which the light must be spread. The area increases as the square of the distance x increases, so that

$$B : 1/x^2$$

where B is the brightness of the image. This will evidently be true for every point and consequently for the whole area ab.

The amount of light entering ab will depend on the area of the opening (usually circular) increasing as this area increases, that is

$$B : d^2$$

where d is the diameter of the circular stop ab. These two proportions may be combined, thus

$$B : d^2/x^2$$

For the ordinary use of the lens in taking pictures (not in enlarging) x is so close to the focal length of the lens that for this work we may replace x by F, and write

$$B : d^2/F^2$$

Hence if we make the diaphragm diameter the same proportion of the focal length of the lens it is to

be used with, we may shift from one lens to another without changing the brightness of the image and consequently without changing the time required for exposure. For this reason the diaphragm is always referred to as a proportion of the focal length. These proportions are what are called the "F numbers," thus "F16" or more strictly "F/16," means that the diameter of the diaphragm referred to is 1/16 of the focal length. A factor of 2 in the F number will mean a factor of 4 in the image brightness; see the above proportion. For ordinary use a factor of 2 is very convenient, so that a series of F numbers are arranged such that the image brightness changes by a factor of 2 and therefore the F number by a factor of the square root of 2. These F numbers are given in the following table in the left hand column.

TABLE 8

F numbers	U. S. numbers
4	1
5.65	2
8	4
11.3	8
16	16
22.6	32
32	64
45.2	128
64	256

The series in the right hand column is called the Universal System numbers and is a little simpler

in use. The number 16 is chosen to agree with the F number, and from this point the numbers run both up and down, always changing by factors of 2 in the number and in the image brightness, but an increase in the number corresponds to a decrease in the brightness, and therefore also to an increase in the time of exposure to keep the exposure the same. Shutters may be obtained marked with either series of numbers, the U. S. probably being the more usual in this country. When referring to the speed of a lens the F number corresponding to the largest stop which can be used with the lens is usually given.

42. **Dry Plate Speeds.**[14]—By the speed of a dry plate is meant the ratio between the opacity in the negative and the exposure required to produce that opacity. A fast plate is one which for a small exposure will give a dense negative, that is the ratio O/E is large. Plate speeds vary a great deal. Not only do they vary when they are meant to, as in different makers' plates or in different brands from the same maker, but different plates of the same brand or even from the same batch will vary somewhat. For speed determination it is necessary to find a reproducible light which shall bear some definite relation to daylight, to fix the conditions of

[14] Watkins' *Photography*, page 297; Sheppard & Mees, *Investigations*, p. 278.

exposure and of development, and to test the resulting negative.

(a) Hurter and Driffield's work has led to the most satisfactory method of measuring and expressing the speed of plates, but it still leaves the difficulty over the light. In Art. 27 Equation 6 gives the relation between opacity and exposure as

$$E/i = O$$

where i is the distance of the point z from the origin and is best expressed in exposure units. This equation is true only for a development factor of unity. Also

$$1/i = O/E$$

from which it appears that 1/i is a measure of the speed of the plate. A somewhat different argument will make this even more evident. In Art. 31 is described the way the characteristic curve shifts with time of development, which for developers not having any potassium bromide, makes the common point z lie on the axis. Fig. 11 gives another example taken from the later work of Sheppard and Mees. The distance of z from the origin is the quantity above called i; i is therefore the exposure which is necessary to bring the densities onto the straight part of the curve and is called the "inertia" of the plate. Obviously if the inertia is large the plate will be a slow one as it will take

a large exposure to bring the plate to the useful part of the curve. Conversely for small inertias. From all which it appears that the inertia, i, is accurately inversely proportional to the speed of the plate. The "H and D number" often given with

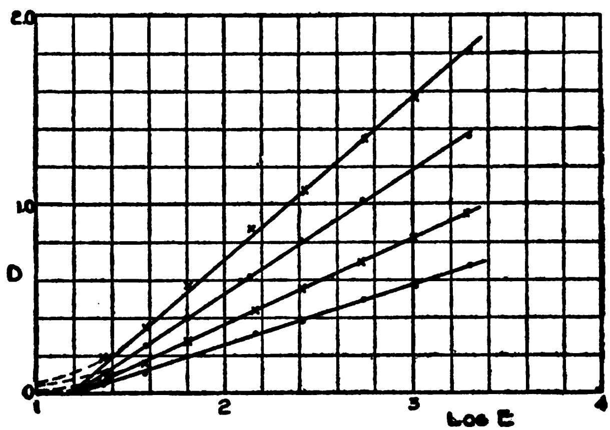


FIG. 11.

English-made plates is the constant 34 divided by the inertia.[15] American plate manufacturers and photographers have hardly used this system at all.

(b) In this country the usual number one sees referring to the speed of the plates is the Watkins number for use with his meter. This is based on calling a plate unit speed when it takes two seconds in bright sunlight, in midday in June, with stop 8 to make a minimum correct exposure. This is a very

[15] See appendix on Plate Speed Systems.

slow plate, and the numbers run from about 20 for a slow process plate to about 500 for the fastest. The numbers increase with the speed and hence the time required for an exposure is in the inverse ratio, the exposure decreasing as the number increases. These numbers are mostly useful for comparison, and one has to remember some exposure to start with as correct, and then modify it according to the plate, time of day, etc. Besides these systems of referring to the speed of plates there are two others one sees in English works, called the Warnercke number and the Wynne number.

43. In connection with the speed of plates, there is an interesting deduction from the characteristic curve as to a method of increasing the speed somewhat. Every part of the plate should receive enough exposure to carry it to the straight part of the curve, that is, an exposure corresponding to the inertia. After that the light from the subject becomes really effective in building up the desired latent image. Evidently one could give a uniform exposure all over the plate, for example by opening the holder to weak, artificial light for a short time; then the picture one wants can be taken with less exposure to the subject—that is the speed of the plate is increased. The increase however is small and hardly worth the trouble, except in unusual cases, as in astronomy, where the observer has to

hold the object to be photographed on the cross hairs of the telescope so that the image will stay at the same place on the plate, often for hours or all night, so that an increase of a few per cent in the speed of the plate will be welcome.

The speed of dry plates are also connected somewhat with what is called the "grain." It will be recalled from the way in which the emulsion was made that the silver bromide will be in the form of little discreet particles, and when the bromide is reduced to silver in development, the silver particles will correspond somewhat with the bromide particles. These silver particles are what is called the grain of the plate. The size varies greatly, depending on the method of making the emulsion, the time of boiling, etc., the fast plates having almost invariably the larger grain. In the slower plates a microscope is required to make them visible but in some of the fast plates they are almost visible to the unaided eye, and under these circumstances will affect the geometry of the picture somewhat. A fine-grained plate is much to be preferred.[16]

44. **Character of Subject.**—The subject may affect the exposure in several ways, by its color, including white, gray and black, by its shadows, and

[16] Microscopic studies of the dry plate are of great interest. See series of articles by Dr. W. Scheffer, *British Journal*, 54, 540 (1907) and 55, 472 (1908).

by its distance. As will be discussed in detail later, Art. 47, the ordinary silver bromide emulsion is most sensitive to the blue light and least sensitive to the deep red. With the ordinary plate, photographs of red objects, a red brick building for example, have to be taken by the scattered white light which is always mixed with the colored light from any object. In consequence red objects need a markedly long exposure. This is particularly true when there is detail in the red which it is desired to have rendered. The best remedy is discussed later under color sensitiveness, Art. 51. Gray or black objects, or any dark-colored objects except blue, shadows where the illumination is weak as in deep windows or doors, under trees or under the brim of a hat, all send a relatively small amount of light to the camera, and the general exposure of the whole subject has to be increased so that these places will get sufficient exposure to record their detail. If the picture includes any near foreground it is apt to be less exposed than the rest of the subject, and any very distant detail is apt to be overlaid with a fog due to the blue haze always present more or less in the atmosphere probably due to fine dust.

45. **Lighting.**—For some typical subjects with the ordinary fast plate (200 Watkins) the actual exposure in June, between 9 a.m. and 3 p.m., with

the sun shining, and using stop 16, are about as follows:

Average subject outdoors, street scenes, figures..	1/15 sec.
Light open landscape perhaps including some water..................................	1/30 "
Sea, clouds and sky, snow......................	1/150 "
Dark outdoor subjects, such as trees............	1/8 to 1 "
Indoors in well lighted room....................	1 to 10 "

Such a table can only be a general guide. In cloudy weather these times must be multiplied by a factor up to 4 or 6, depending on the amount of cloudiness. The following table will serve as a guide to the effect of the time of day and the time of year.

TABLE 9

a.m. p.m.	June	May July	April Aug.	March Sept.	Feb. Oct.	Jan. Nov.	Dec.
12 or 12	1	1	1.25	1.5	2	3.5	4
11 " 1	1	1	1.25	1.5	2.5	4	5
10 " 2	1	1	1.25	1.75	3	5	6
9 " 3	1	1.25	1.5	2	4	12	
8 " 4	1.5	1.5	2	3	10		
7 " 5	2	2.5	3	6			
6 " 6	2.5	3	6				
5 " 7	5	6					

To keep such data as this in portable form and to help in the calculations there are a great number of exposure calculators and exposure meters on the market. They are mostly applications of the slide-rule principle, one scale taking account of the difference in subjects, others of the time of day, of

the time of year, of the speed of plates, and of the stop. Another class of these exposure meters includes a device for measuring the photographic value of the light. This is accomplished in two different ways. In one class, which includes the Watkins, the Wynne, and the Johnson meters, the light is allowed to fall upon a piece of light sensitive paper and the time noted which it requires to darken to match a neighboring gray patch. This time is a measure of the photographic value of the light and is used to calculate the exposure. In the other class, which includes Heydes Actino-Photometer, a wedge of blue-gray glass is placed in front of one's eye, and by shifting to the darker end of the wedge the detail observed begins to become invisible. The position of the wedge at which this occurs gives a measure of the amount of light and is readily used to calculate the exposure. The second class has some points of superiority—greater rapidity in weak light, measurement of the light coming from the subject, not of that falling on it, freedom from variation in the sensitive paper, but on the other hand it depends on the constancy of the eye. Any of these light meters are very satisfactory helps and will quickly pay for themselves in plates saved, but they have to be used with judgment, as they cannot take care of the great variety of actual circumstances.

CHAPTER III

PROPERTIES OF THE GELATINE DRY PLATE—COLOR SENSITIVENESS

46. Anyone using the ordinary silver bromide plates will soon notice certain peculiarities when they are used for making the usual monachrome (black and white) prints of colored objects. Blue objects, even dark blue ones, will appear almost white in the print, while red, yellow, and green will appear in this order, from black to gray. The brightness of the image for different colors is not at all as the eye sees them. There is also a second difficulty in many colored subjects. If the exposures are made right to show the different shades of blue, then the reds are uniformly black, showing no difference between the different shades of red, that is giving no detail in the red. By making very much longer exposures a certain amount of detail can be obtained in the red, but then all the detail in the blue objects will be lost; they will appear uniformly white. The order of decreasing action of the different colors in making their record on the plate is, violet, blue, green, yellow, orange, red,

that is practically the short to the long wave lengths in the visible spectrum. This is not the order at all for visual color brightness, yellow being the brightest color. As a matter of fact, the ordinary plate does not render visual color brightness at all. We have become so used to black and white pictures showing the shadows and the geometric form, that the lack of this less important detail is not felt, unless the object be very brightly colored.

It will hardly be necessary to point out that color is an attribute of light, that the color of an object is merely the result of its power of reflecting some of the colors of light and absorbing others. Most colored objects reflect light which is a mixture of colored lights, and we call it an impure color as distinct from a pure color due to one wave length of light. To investigate this color rendering of the plate it is advisable to use pure colors and get their effect on the plate, and then the effect of the impure colors will be the sum of the effects of the different colors composing them.

47. **Color Sensitiveness Curves.**— There are various means of separating the different pure colors composing white light into a band of pure colors called the spectrum. The best of these means for our purpose is probably the one we use in the laboratory, a grating, since it spreads the colors out evenly all along the spectrum. Reference must be

made to any text book on physics for an explanation of its action. Accepting this grating spectrum then as giving us the sum total of the different colors of white light distributed in strict proportion to the wave length, it will only be necessary to let this band of color fall upon the sensitive plate and then develop it as usual, in order to test the effects of the different colors. To get the greatest amount of information it is best to make a series of increasing exposures so that the part of the light which has only a small action will be able to record that which it has. For the ordinary silver bromide plate the action is greatest in the blue-violet, decreasing rapidly to almost nothing in the yellow and red and only a little less rapidly in the violet and the ultra violet. If we plot density vertically, and color (better wave length) horizontally, we will have a curve which will represent the color sensitiveness of the plate, since the sensitiveness is approximately proportional to the density produced. In the same way we could measure and represent the color sensitiveness of plates made of the other silver haloids, silver chloride and silver iodide; see Fig. 12. In the visible part of the spectrum they do not differ very greatly from each other.

48. **Dyes.**—Some time before gelatine plates were known, a German worker, Professor Vogel, discovered that treating the collodion plates before

exposing with certain dyes changed their color sensitiveness very markedly. Since his work the number of dyes known to have such action has increased very greatly.[1] It was a very direct experiment to

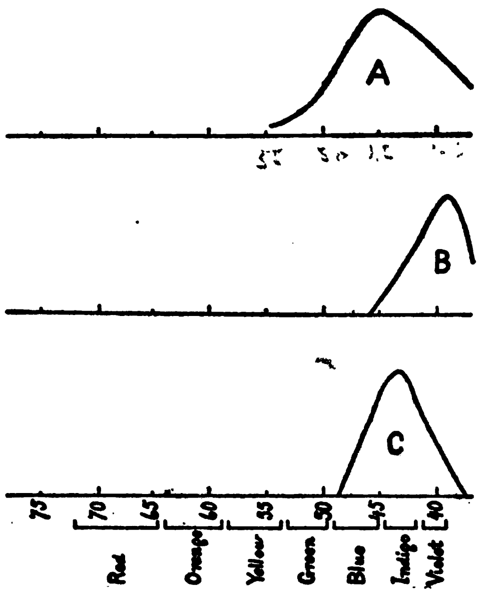


FIG. 12. Curve A is the color sensitiveness of silver bromide gelatine emulsion. Curve B that of silver chloride gelatine emulsion. Curve C that of silver iodide gelatine emulsion.

try the same thing with gelatine dry plates, where they were found to have the same kind of action. It has been found that the dye has to actually color the silver bromide particles themselves; merely col-

[1] R. J. Wall, "Recent Work in Color Sensitizing," *British Jour.*, 54, 365 (1907).

oring the gelatine does not give the action referred to. That is only those dyes which are actually absorbed by the silver haloid change the color sensitiveness. The amount of the dye required is very small; the usual bathing solution for all the dyes is about 1 part in 100,000 water. As a matter of fact, the amount of staining of the silver bromide depends very little on the amount of dye in the solution; the particles absorb so much and then will absorb no more. From this, as one would expect, it is very difficult to wash the dye out, practically impossible in fact. Enough of it to give a very noticeable effect on the color sensitiveness remains there after prolonged washing. The dye solution is composed of very fine particles of the solid dye suspended in water (colloidal solution) and the smaller these particles are, the better they are absorbed by the bromide. Dilution of these solutions divides the particles, which is one reason that a dilute solution works better than a more concentrated one.

Only a few of the very great number of known dyes have this property, and the dyes have been very extensively tested, two workers recording the testing of 600 dyes, for example. There is not any apparent rule as to what dyes will prove useful for this purpose, and dyes which are very closely related in composition are often very different in this

property. It is worthy of note also that the particular haloid of silver used influences the action of the dye quite materially, some dyes serving for one when they will not act with the others. The vehicle in which the haloid is carried has also a marked action; dyes serviceable for gelatine plates will often prove quite useless for collodion.

Why certain dyes should have this sensitizing action on the silver bromide is not at all evident. Some of these dyes are bleached by light, and one theory proposed assumes that the compounds formed by this bleaching cause or help the reduction of the silver bromide in their neighborhood. Against this explanation is the fact that the ease of bleaching and the sensitizing action are not apparently related; dyes which bleach easily do not give the best or greatest color sensitiveness, and some dyes which hardly bleach at all give good color sensitiveness. Apparently the best one can say is that the silver bromide dye compound, or complex as some writers call it, acts toward the other colored lights as the simple silver bromide does toward blue light. Later we will consider some of the theories for this action.

49. **Absorption Curves.**—Draper's law for the action of light on substances only needs understanding to make clear its probable truth, and it has also been proved experimentally. It is to the

effect that only the part of the light which is absorbed can produce chemical—rather photochemical—action. In other words, light which passes right through a substance will not produce any change in it. That is to say, if we determine what colors of light the dye absorbs when it is used to dye the silver bromide, these will be the colors for which it will sensitize the plate. The colors the dye absorbs when in solution in water or in alcohol are generally much the same as when in the silver bromide, so that if one lets the spectrum pass through a solution of the dye, the colors which are missing will be the colors for which the dye will sensitize the plate if it changes the sensitiveness at all. One places a weak solution of the dye in the path of the beam of light forming the spectrum, and then measures the amount of each color which has disappeared, that is measures the absorption. These values are then plotted vertically against color horizontally, giving an "absorption curve" [2] which for a yellow-green absorbing dye, for example, will resemble Fig. 13-B. To the eye the dye solution will appear the complementary color to the ones absorbed, that is in this case red.

50. **Absorption and Sensitizing.**—Now let us dye an ordinary dry plate with this yellow-green absorb-

[2] See also Mees, "Atlas of Absorption Spectra."

ing dye, expose it to the spectrum, develop it and measure the resulting densities. By plotting these densities against color we will get a "density-color" curve (Fig. 13-C). As well as the natural color

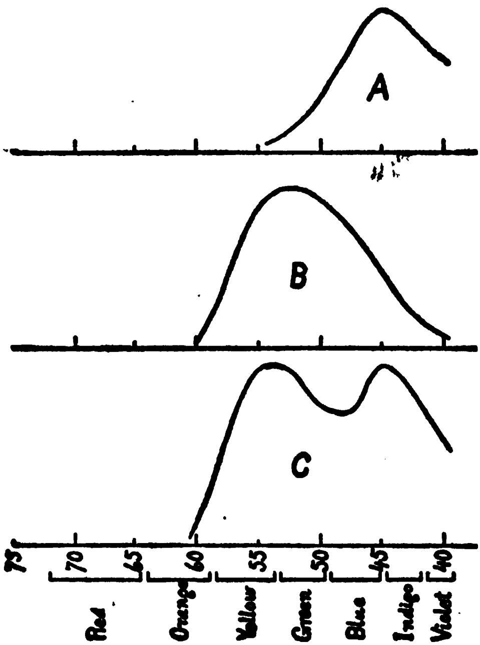


FIG. 13. Curve A is the color sensitiveness of silver bromide gelatine emulsion. Curve B the absorption curve of eosine in water. Curve C the color sensitiveness of silver bromide gelatine emulsion dyed with eosine.

sensitiveness maximum in the blue-violet (Fig. 13-A), which is always present in dry plates, we have a secondary maximum in the yellow-green due to the dye and corresponding in position to the maxi-

mum in the water-solution absorption curve above except that it is shifted slightly towards the red end of the spectrum. These color density curves are also color sensitiveness curves, as the sensitiveness is approximately proportional to the density under these circumstances.

51. **Practical Application.**—The curves we get by the use of one of these dyes are always irregular

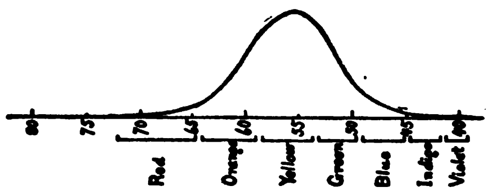


FIG. 14. Luminosity curve for the average eye.

with peaks and hollows and not of the kind we would choose for ideal photography.[3] If we wish to represent things exactly as they appear to the eye, then the plate should have a sensitiveness curve like the curve for the action of the different colors of light on the eye, that is what is called the luminosity curve; see Fig. 14. While visually correct this would sacrifice detail, particularly in the violets and blues. For the general case it is better to ask that the photograph show all the detail possible in

[3] For an excellent discussion of this whole subject, see *The Photography of Colored Objects*, by C. E. K. Mees, or *Das Arbeiten mit Farbenempfindlicken Platten*, von Dr. Ernst König, G. Schmidt, Berlin, 1909.

all the different colors. This requires that the sensitiveness in all the colors should be as nearly alike as possible, that is the color sensitiveness curve

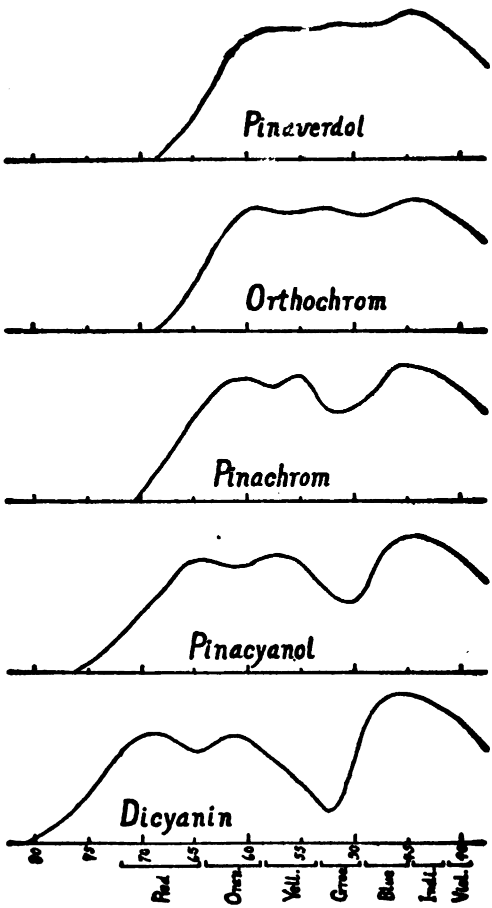


FIG. 15.

should be a straight line running horizontally through all the colors. This ideal is approached fairly closely by a number of panchromatic plates now on the market, with however some sacrifice of plate speed. The sensitiveness curves obtained by the use of certain good dyes[4] are given in Fig. 15. It will be noted that the curves for the different dyes are very far from the ideal curve desired, although these dyes are among the best known for this purpose. The natural sensitiveness in the blue-violet exceeds all the rest and there are usually quite pronounced dips in different colors. These dips or minima occur at different colors with the different dyes so that it would look likely that one could avoid them by the use of two of the dyes at once, that is dye the plate with a mixture of two or more dyes, or successively with different dyes. When one tries the experiment this way it is soon evident that the effect obtained is not at all the sum of the effects of the two dyes when used separately. It becomes necessary to try the effect of the dyes when used together by actually making the experiment. Such experiments have shown that it is possible to make a fairly good plate by a mixture of certain dyes in certain proportion[5] and some of the com-

[4] Some of the best dyes may be obtained from The Bayer Co., 117 Hudson St., New York; Farbwerke Hoechst Co., 122 Hudson St., New York.

[5] See R. J. Wallace, *Astrophysical Journal*, 26, 317 (1907).

mercial plates may be made this way, as it is probably the simplest method. But the interference of one dye with the other in the silver bromide can be avoided by adding one dye to part of the emulsion and another dye to another part and so on as far as necessary to build up the curve desired. Then after the different parts of the emulsion have been washed ready for coating the plates, they are mixed thoroughly with each other; and the color sensitiveness of the resulting plates will be that expected from the way the different dyes act when alone. In this way it is possible to build up a sensitiveness curve which is almost straight, the remaining difficulty being the too great sensitiveness in the blue-violet and usually a small dip in the green and in the deep red. There are a variety of names used for such plates by the manufacturers, but the term Panchromatic is probably as good as any.

52. **Screening Action.**—Besides the direct sensitizing action of the dye on the silver bromide there is another action possible which has to be taken account of; if the dye stains gelatine strongly or if it is not well washed out, then the surface layers of the emulsion will absorb the light the dye absorbs, and this absorbed light will not affect the silver bromide. Usually it is an undesirable action, but it can be used to cut down the blue-violet maximum

by staining the gelatine with a dye[a] which will absorb some of the blue-violet light and so prevent this part from reaching the silver bromide, and so reducing this maximum to any desired extent.

53. **Color Screens.**—Attempts to build up the color sensitiveness to equality all through the spectrum all meet finally the difficulty of the invariably greater sensitiveness of the silver bromide itself in the blue-violet. To get over this difficulty there remains finally only the objectionable way of cutting down the amount of the light in those colors for which there is too great sensitiveness, so as to leave them on a footing of equality with all the other colors. This is objectionable because it necessarily increases the exposure required, that is reduces the apparent speed of the plate. This cutting down can be accomplished by passing the light through a transparent, colored material before it is allowed to fall upon the plate. The more convenient of these "color screens" are made by a layer of dyed gelatine cemented between two pieces of glass and fastened in a tube which can be slipped over the front of the lens of the camera.

To accomplish the desired result it will be evi-

[a] Meister, Lucius & Brüning, Hoechst, o. M., advertise Erythrosine—Filter Yellow for subduing the blue sensitiveness, and the same dipping bath may contain pinachrom or pinacyanol for sensitizing to the other colors. American agents are H. A. Metz & Co., P. O. Box 753, New York.

dent from what has preceded that the color screen must be fitted to the particular plate with which it is to be used, and in order to cut down only those colors desired and to the amount desired, the color of the screen must be very carefully adjusted. A study of their absorption curves will show what dye to use, or often a mixture of dyes is needed, and in the ordinary case it will absorb principally the blue and violet light so that the screen will appear yellow or red. The adjustment of the amounts of the dye to use can be calculated approximately from the absorption curve, but the careful final adjustment of the amount or amounts, if more than one dye be used, can only be accomplished by making a screen and trying it on the plate.[7] A very small change in the amounts of the dyes produce considerable changes in the desired effects.

To consider a particular case suppose we wish to make a color screen for use with a plate dyed with only one dye, pinachrom; refer to its color sensitiveness curve in Fig. 15. If we wish to make the effect of the green and red light from the object have as great an effect on the plate as the rest of the colors, it will be necessary to absorb a large proportion of the blue and violet and some of the orange. The plate is very little sensitive to deep

[7] R. J. Wallace, "Color Filters," *Astrophysical Journal*, 24, 268 (1906).

red, and if we wish to hold the other colors down sufficiently to make them all equal, it will make the exposure extremely long, possibly hundreds of times the unscreened plate. This makes the exposures unreasonably long, and a compromise is usually made by neglecting the deep red so that the increase in the exposure will not be too great. Such a plate as this is usually called isochromatic where it has very pronounced gaps in the color sensitiveness curve, as distinguished from panchromatic where the gaps (or dips) are small or absent. A screen for a good panchromatic plate may hardly double the exposure.

It will be at once apparent that any screen will not usually do for any plate but they should be made to fit each other. Since all plates need screening, mostly in the blue-violet, any screen made for an isochromatic plate will help most other isochromatic plates. There are a lot of different color screens on the market with which the exposure will be increased anywhere from twice to fifteen times, and it is a matter of pure guess how they will affect the picture of a multi-colored object taken on any chance plate. It is much better to buy a screen made for a particular plate and use it with that plate.[8]

[8] Eastman Kodak Co. & Cramer Dry Plate Co., St. Louis, both make screens adjusted to their own makes of plates. They both issue excellent booklets on the general subject.

54. **Rendering Color Contrast.**—Color screens have another application which is often of considerable value. Suppose we wish to take a picture of an engineering blue print. If taken in the ordinary way on the undyed plate the blue parts of the picture will be very nearly as effective in producing density in the negative as the white parts, that is the resulting negative will have very little contrast and the print made from the negative will be so flat as to be almost worthless. This difficulty can be avoided by using a color screen to absorb the colors of light which are common to the white and blue parts of the original, and making the negative by the use of the remaining colors (or part of them) which the blue subject absorbs and to which it therefore appears black. Suppose we use a plate which is sensitive to orange light and put a screen over the lens through which only orange light can pass, that is it is to absorb all the other colors. This will of course require a large increase in the exposure. The blue parts of the original absorb orange strongly so that no light will go from these parts to the plate, while the white parts will send all the orange, as they absorb almost none. That is there will be strong light action where the subject is white and almost none where it is blue, and the result will be a good contrasty negative. The same idea can be applied to increase contrast be-

tween any two colors if a suitable screen [9] is to hand and it is particularly useful in microphotography where the microscopic specimen is usually stained and in pictures of stained wood articles to show the grains. For their general use in rendering clouds and distance see Art. 132.

[9] Wratten & Wainwright, Croyden, England, and Eastman Kodak Co., Rochester, N. Y., make a full line of such screens.

CHAPTER IV

LATENT IMAGE THEORIES

55. **Basic Facts.**—Before describing any of these theories it will be well to review the important facts about the latent image. If light be allowed to act for a short time on a sensitive film, it produces no visible change, but it does produce a change which makes the film act differently towards some reagents. Reducing agents act more readily on the exposed parts while the same parts fix more slowly in hypo. This state which shows these differences in the different parts of the film we call the "latent image."

This latent image may be destroyed by a number of reagents, such as nitric acid, free halogens or bodies which readily give up halogen like ferric chloride, $FeCl_3$, cupric chloride, $CuCl_2$, mercuric chloride, $HgCl_2$, potassium iodide, KI, and the halogen acids, HCl, HBr, and HI, and most strong oxidizing agents, such as potassium persulphate, $K_2S_2O_8$, and potassium permanganate, $KMnO_4$ in acid solution.

If the film carrying the image be allowed to stand

the image will gradually fade out, the time required varying very much for the different kinds of sensitive films. A great many things retard or hasten the process; some papers which have a lot of chromate in the film to harden it will fade out in a few days. Most good plates keep the image a very long time, and instances are on record where good negatives have been developed years after exposure. The action of the light on the film does not begin with the first light striking it, but the action gradually builds up as more light is added. This starting action quickly fades out if only a small quantity of light is allowed to act, and this light producing small action has to be added again in the next exposure. After a normal exposure the formation of the latent image does not cease with the stopping of the light addition but continues for some time, minutes perhaps, and then the gradual fading out begins.

It is possible to make an artificial latent image by allowing a dilute developer to act on a plate, and also by heating the plate somewhere above 100° C.

An enormous amount of experimental work[1] has been done on the latent image and its properties, and some of these results will be referred to later on, but till the theories have been described the

[1] Sheppard & Mees, "Investigations," Chap. VI.; Bancroft, "The Latent Image," *Jour. of Phys. Chem.*, 17, 93 (1913).

above will be the main facts which the theory must account for.

56. **Theories.**—There are a considerable number of such theories, but for our purpose we will refer only to four. They are that the latent image consists of:

1 A physical modification of the silver salt.
2 Small discrete particles of silver (silver grain hypothesis).
3 Silver sub-bromide in the silver bromide particles.
4 A solid solution of silver in silver bromide particles.

57. The *first theory* is that the action of the light is to produce some physical change in the silver bromide, such as for example shattering the particles and the fragments would probably be more easily developed than the unaffected particles (compare pressure marks). Or it may be to polymerize the silver bromide or to unpolymerize (that is to divide the molecule into smaller ones, unpolymerize, or to gather several molecules into a larger one, polymerize), or some writers do not attempt to say what the nature of the physical change is. Then assuming that the change makes the particle more easily developed, the theory will account for the latent image as far as its developing properties are concerned. But this theory fails completely to account for the destruction of the latent image by all the chemical reagents given above; there is no sim-

ple way in which the reagent can be made to gather the shattered particles together again. The theory is not very generally held but deserves mention for its place in history and for its simplicity.

58. The *silver grain* hypothesis begins with the experimental fact that light separates some of the bromine from the silver, so that there are left small particles of free silver scattered through the gelatine but not necessarily in contact with the remaining silver bromide. When the developer comes along it is assumed to carry silver from the silver bromide grains in the neighborhood and deposit it on the silver grain. This assumption had as justification Eder's experiment, where he touched a plate in the developer with a silver wire and there was a deposit of silver at the point of contact with the film. It was soon found that the silver wire had to press on the film—compare pressure marks—finely divided silver lying on the film would not produce the deposit. But nevertheless it is an experimental fact, silver particles will grow in size in the film in the presence of the developer and more quickly if there is some silver nitrate added to the developer. But without the presence of the silver nitrate the growth is too small to be of any use practically and will not account for the growth of the silver image. Even if finely divided silver is actually incorporated in the film itself by being

mixed with the molten emulsion, it will not produce appreciable development unless the silver particles are actually in contact with the silver bromide particles or actually incorporated in them; in which latter case the film develops vigorously. But this case is the theory 4, page 91. Other things also tell against the silver grain theory, as for example the fact that the latent image is not destroyed by dilute nitric acid whereas finely divided silver is very readily dissolved by it. Other silver solvents act similarly. So that this hypothesis has had to be modified to give the fourth theory above.

59. The *silver sub-bromide* hypothesis (theory 3, page 91) is one which has held the field for a long time and possibly is the most popular theory yet. It is also based on the experimental fact of the separation by light of some bromine from the silver bromide, but it assumes that this takes place right in or on the silver bromide particle and that it leaves a compound of silver with bromine which therefore is richer in silver than the ordinary silver bromide. The composition of this compound is quite unknown, but it is often spoken of as if it were Ag_2Br, for which there is no real justification. Cary Lea made a lot of substances resembling the latent image in properties and which contain less bromine than the ordinary bromide. They were made usually by taking some of the bromine from silver

bromide, that is reducing it by substances like developers. The compounds are variously and often beautifully colored; dilute nitric acid will not take the extra silver out of them nor will hypo dissolve them completely, but the latter always leaves a residue of metallic silver. Other experiments have shown that some of the metals are soluble to some extent in their fused chlorides. Addition of a free halogen to the latent image destroys it if suitable precautions are taken to prevent the halogen being all taken up by the gelatine. When a plate is blackened by light free halogen can be detected by the odor; even a short exposure to light produces a visible change in the color of the plate even though no bromine seems to be given off. Probably the bromine is taken up first by the gelatine till presently it becomes saturated. All of these facts can only mean that there will be an excess of silver in the light affected haloid, and experiment has shown that this sort of a haloid is easily reduced. Whether this excess of silver is present in the form of subbromide or in the form of very finely divided metallic silver suspended in the rest of the silver bromide (that is in colloidal solution), is a point very hard to determine directly, but the indirect evidence favors the free silver hypothesis.

60. The fourth hypothesis is the *solid solution* theory, which is referred to in the last line of the

preceding paragraph. To repeat, the latent image consists of very finely divided metallic silver suspended in the solid silver bromide much as fine particles would be suspended in water. Such suspensions are now called "colloidal solutions." Moreover, solutions do not need to be liquid; many cases are known where a solid dissolves other substances, and these cases are usually referred to as "solid solutions," so that in the case of the silver in the silver bromide it will be a "colloidal solid solution." In this connection it has been shown experimentally that silver bromide precipitated from solution containing also suspended materials carries down these suspended materials imbedded in the precipitate. This is not limited to suspended solids but takes place even with substances which are in true solution. These carried-down materials may be the dyes that we have been studying a few pages back, or other metallic chlorides, or gelatine, or albumen, or a great many other substances. They are carried down even though they are present in very small amount and it is almost impossible to wash them out completely from the precipitate.

The presence of these small quantities of inclusions may affect the sensitiveness of the plate very materially, as in the case of the dyes, or in the case of mercuric chloride or of ferric chloride, in which latter cases the sensitiveness will be greatly reduced.

The presence of 0.001 gram of gelatine in 10,000 cc of solution from which the silver salt was precipitated distinctly increased the sensitivity. The amount of silver actually set free by the light and thus forming the latent image must be very minute, but all these facts go to show that it may be quite sufficient to accomplish the result of making the silver haloid more easily reduced. Finely divided silver may be carried down in the same way by the precipitated silver haloid. The color of such finely divided silver varies with the state of division of the silver from white to pink, rose colored, red, brown, blue, to black. The color of the silver haloid precipitate carrying the finely divided silver agrees exactly with it. Treatment with strong nitric acid does not take out the extra silver unless the treatment is very prolonged—25 hours at 100° C in one case. Almost any means of producing the haloid, and at the same time reducing some of it to metallic silver, will give these colored precipitates. The colored chloride precipitate dissolves very slowly in ammonia solution, leaving a residue of metallic silver which may amount in extreme cases to 7% of the haloid but is usually around 1%. Hypo or ammonium chloride solutions will do the same. On exposure to light all these colored haloids blacken very rapidly, more rapidly than the uncolored. They are all very readily reduced to metallic sil-

ver by developers. In fact, the behavior of these compounds is exactly like that of the latent image.

If an exposed plate be fixed in plain hypo it is still possible to get a negative from it by developing it in a solution which will deposit metallic silver. Plain hypo solution does not dissolve metallic silver even when the latter is finely divided, but if acid bisulphite be added to the plain hypo solution, the latent image will be destroyed, that is it can no longer be developed by a solution which deposits silver, because the acid bisulphite dissolves the silver forming the latent image at the same time that the hypo is dissolving the rest of the silver haloid. The silver particles forming the latent image, being bedded in the silver haloid, are protected by it from such reagents as nitric acid, and the presence of the silver particles makes the particle of haloid less soluble in its solvents but much more readily reduced by developers.

61. **Conclusion.**—From all this work it will appear that the hypothesis of the formation of silver sub-bromide is quite unnecessary to explain the experimental facts, the colloidal solution theory, being simpler, is to be preferred. Also in a number of cases the latter hypothesis is in better agreement with the experimental facts, as for example in the colors of Cary Lea's photohaloids. It seems best to consider the latent image as consisting of silver

particles suspended in silver bromide in colloidal solution—that is in a very fine state of division. The action of the light has been to set free some bromine which combines with the gelatine, leaving a minute portion of metallic silver incorporated in the particle of silver haloid, where its mere presence greatly increases the ease of reduction.

CHAPTER V

NEGATIVE DEFECTS

62. The following series of defects in negatives are of frequent enough occurrence to require a somewhat extended discussion.

1. Thin from (a) Lack of sufficient silver bromide on the plate
   (b) Underexposure
   (c) Underdevelopment—Intensification
2. Dense from (a) Overexposure
   (b) Overdevelopment—Reduction
   (c) Fog, from light, from age, or from defective emulsion.
3. Frilling,
4. Dust marks,
5. Air bells,
6. Black spots,
7. Finger marks,
8. Pressure marks,
9. Halation,
10. Oyster shell markings,
11. Stain,
12. Bubbles in the gelatine,
13. Drying troubles.

63. **Thin Negatives.**—The negative may lack sufficient printing density so that detail visible in the negative will not show in the print. This may be due to a number of causes. In the first place

the total silver bromide put on the plate in the emulsion by the maker may not have been sufficient; that is there may not have been sufficient of the emulsion or the emulsion may have been too poor in silver bromide. The remedy is to make another negative on another make of plate. But it rarely happens with reliable makers of plates and usually requires direct experiment to show that it is the cause of the thinness. Nevertheless if one has a series of thin negatives of which the exposure and development can be relied upon, then it will be worth while to try another make of plate to see whether it will help the trouble.

Or it may be *underexposed,* in which case the shadows will lack detail and the print will be flat. It may even have what resembles a white veil all over the print, which one sees very frequently in "snap shots." Occasionally one can build up sufficient printing density, so that the print becomes clear, but the intensification will not find out any more detail than there is already there. As well as lacking detail the resulting print, after the intensification, is sure to be harsh and without half-tones, in general unsatisfactory. If the underexposure is at all serious the only real remedy is another negative giving more exposure, 2, 4, or 8 times as much; there is seldom any use in changing the exposure in less than factors of two.

Or the negative may be *underdeveloped,* due to too short a time in the developer, to too weak, or too cold a developer. In this case there will be more detail visible in the negative generally, and particularly in the shadows. Intensification will set the case right exactly as the process simply supplements, or rather continues, the incomplete process of development. In this case, a satisfactory intensification is a complete remedy, but in the other cases it is only a palliative, though it will often improve matters.

That is to say, in the great majority of cases both intensification and reduction are attempts to patch up previous faulty work. In most cases the best remedy is to repeat the work, correcting the fault. In case it is not possible to repeat the exposure or in case the subject is a difficult one, these methods may be the only available resource.

64. **Intensification.**—A very great many processes of intensification [1] have been described, any one of which will undoubtedly add density to the silver image. With many of them staining is difficult to avoid. With most of them the intensification is very irregular both on different parts of the same plate and on different plates. The added density is not proportional to the original density

[1] For example see B. J. *Almanac for 1915*, p. 583, or *Photo-miniature,* No. 74.

nor does it vary from the proportionality in any definite way, so that the gradation in the resulting negative is largely a matter of chance. In some cases this is due to the intensifier actually reducing part of the image while intensifying the rest. Many workers recommend the use of such intensifiers [2] (and reducers) as a means of controlling the gradation in the negative. For all record photography such manipulation is to be condemned, but in pictorial photography it has a place as giving the worker control, even if uncertain, over the character of the picture which in such work has no necessary relation to the original subject.

A method which may be relied upon to give proportional intensification is the one advocated by Chapman Jones [3] and described in detail in the Manual, Exp. 10; see also Art. 24. The density is almost exactly doubled by one application and the gradation is not altered. After the final washing the process may be repeated with similar results. In negatives where gradation is not important, as in line drawings and where great intensification is desired, the bleached, well-washed negative may be immersed in a dilute solution of sodium sulphide,

[2] See, for example, W. F. Ellis, *American Photography*, 8, 293 (1914).

[3] See *Photominiature*, No. 74, page 67, or also *British Journal*, 57, 495 (1910).

by which both the silver and the mercury chlorides will be changed to brown sulphides, thus:

$$2AgCl + Na_2S = Ag_2S + 2NaCl$$
$$2HgCl + Na_2S = Hg_2S + 2NaCl$$

and the density of the negative will be very greatly increased, but the process cannot now be repeated.

65. **Overexposure.**—Too *dense* a negative may also be due to several causes. The negative may have been exposed much longer than was necessary and yet hardly be what should be called overexposed. That is the densities may still lie on the straight part of the characteristic curve. The prints made from it will be correct in rendering of the light and shade, but the time of printing will be long. The safest remedy is to spend the time required for the printing. If it can be arranged to use daylight, or in extreme cases sunlight, the exposure can readily be made as short as will be manageable. If, however, the exposure has been so great that the densities have got beyond the straight part of the curve to any extent, the plate will be lacking in contrast and look fogged all over. The printing qualities may be improved by a complicated process of reduction and intensification, requiring considerable skill and familiarity with these processes, and it is only in rare cases that it is profitable. Ordinarily the print will be flat, that is lacking in contrast. In

such cases, the simplest, quickest, and best course is to take another negative with a very much shorter exposure, 1/4 or 1/8 or even less, depending on the degree of overexposure.

66. **Overdevelopment.**—The great density may have been due to too long in the developer, to too concentrated a developer, or to too warm solution, any one of which will carry the development too far, that is give too large a development factor, which will mean the exaggeration of the contrasts and the increase of any halation which may have been present. The halation deposit being mostly on the under side of the film, it is practically impossible to remove it without at the same time destroying the negative detail. If the plate is important and another exposure too difficult to get, the best plan is to spend the time necessary to make the exposure, shading the plate locally so as to force the exposure at the dense places. A few trials will often enable one to make quite satisfactory prints. Lacking any great amount of halation, the best remedy is one of the reducers.

67. **Fog.**—The large total density may be at least partly due to *fog*. This has been referred to already in Arts. 19, 34 and 37. It is a deposit of silver in the film of the negative which is not the result of the action of the light used to make the negative exposure. Overdevelopment is liable to

include as a result a lot of chemical fog. If this is even over the whole plate it will merely mean longer printing exposure, but it will not be even, as can readily be seen.[4] The amount of fog formed at any given place in a given time depends on the amount of unreduced silver haloid at that place. From which it follows that the fog will be greatest at the places of least density in the negative. Carried to the extreme, this will mean that the negative will get black all over, which actually happens if it is kept long enough in the developer. The effect of the greater fog in the thin places will be to reduce the contrast in the negative, so that while normally the effect of long development is to increase contrasts, this increase of contrasts may be partially or completely offset by the formation of fog. Reduction will help materially if the right reducer be used, that is one which will dig out the thin parts more proportionately than the thicker, which will tend to undo the fogging. The fog is liable to be a good deal on the surface, which will help its removal by the reducer. Besides chemical fog referred to above another common cause is "light struck," due to some unpremeditated exposure of the plate to light. The camera or plate holders may not be tight (if possible never let the

[4] Lumiere & Seyewetz, *Brit. Jour.*, 54, 195 (1907); Sheppard & Mees, *Investigations*, page 59.

sun shine directly on the plate holders), the dark room light may not be safe, or the dark room may not be really dark. In case it is even over the whole plate, the safest procedure is to spend the required longer time over the printing, as besides the risk of mishap reduction will often change the contrasts so as to impair the printing quality. In case the light struck parts are not evenly distributed, as is usually the case, attempts at reduction usually do not improve matters; the safest procedure is to manipulate the printing exposure by shading part of the print with the hands or cut-out cardboard so that the denser parts will receive the required extra exposure. It will take a number of trials to get the right proportion between the various exposures when satisfactory prints can often be made. In case a large number of prints are desired it will pay to make a new negative from one of the best obtainable prints and from which good prints can be readily made.

Fog may be due to the plates being old, or having been kept in damp or hot places. The edges of such plates usually show it more than the middle; sometimes the edges are quite thin, due to the falling off in sensitiveness of the film. Plates go bad very quickly when kept in damp places.

From the discussion of the manufacture of dry plates you will understand that the plates can be

badly made so that they fog heavily in the developer. But with reliable makers this rarely happens.

68. Reduction.—There are a great many reducers which one might use, just as there are a great many intensifiers. They can be divided into three general classes.

(a) Those which increase the density ratios by removing more silver proportionally from the thin parts of the image than from the denser parts. An example of this class is the ferricyanide-hypo reducer (also called Howard Farmer reducer). See Manual, Exp. 11.

(b) Those which do not alter the density ratios, that is, remove proportionate amounts of silver from all parts of the image. The potassium permanganate reducer comes near to this though really belonging in class (a).[5]

(c) Those which reduce the density ratios by removing more proportionately from the denser parts of the image. The best example is the ammonium persulphate reducer.

The microscope[6] shows that class (a) sinks into the film, dissolving practically all the silver particles as it goes in. The microscope also shows that the silver is distributed deeper into the film in the

[5] Huse & Nietz, *Scientific American Supplement,* Dec. 23, p. 405 (1916).

[6] Dr. W. Scheffer, *Brit. Jour.* 54, 540 (1907), and 55, 472 (1908).

denser parts, less deep in the thinner parts. The reducer mentioned then acts just as if one took a shaving off the surface of the film, which might easily remove all the deposit from the thin places while leaving untouched a good share of that in the denser places, that is, of course, changing the proportions among the densities.

The ammonium persulphate has a very peculiar action. The microscope shows that it attacks the denser parts of the image strongly, while the thin parts are almost proof against it, with the results that it cuts down the contrasts as much as desired. Both the solid ammonium persulphate and the solution in water (3%) used as the reducer are very unstable, decomposing steadily so that the more stable one, the solid, will keep only a few months.

The chemical action of all these reducers is a good deal alike. They change the silver from metal to a metallic salt which is soluble in water or in some other reagent and is thus removed from the film. Thus for the ferricyanide

$$2Ag + 2K_3Fe(CN)_6 = K_4Fe(CN)_6 + K_2Ag_2Fe(CN)_6$$

The resulting potassium ferrocyanide is soluble in water and the potassium silver ferrocyanide dissolves in the hypo thus

$$K_2Ag_2Fe(CN)_6 + 3Na_2S_2O_3 = Na_2K_2Fe(CN)_6 + Na_4Ag_2(S_2O_3)_3$$

And for the persulphate reducer thus,

$$(NH_4)_2S_2O_8 + 2Ag = 2AgNH_4SO_4 = Ag_2SO_4 + (NH_4)_2SO_4$$

and both silver and ammonium sulphates formed are soluble in water.

69. **Local Reduction.**—At times it may be advantageous to reduce part of a plate and leave the rest unchanged. This can be done by applying one of the above reducers with a brush where it is desired to reduce the deposit, and rinsing the plate frequently in water to stop the reducer spreading and to avoid marks. It is not possible to limit the reduction at a sharp line but it can be made to give nicely graded effects. Fairly sharp line limits to the reduction may be obtained by rubbing the dry film with a cloth wet with absolute alcohol, which does not soften gelatine. The surface of the film can be rubbed off, carrying with it the silver deposit and so reducing the density locally. This may also be accomplished by grinding off the surface of the dry film with an abrasive powder or by scraping it off with a sharp knife. It is very difficult to do any of these things so that they will not be seen easily in the print.

70. In normal exposures developed without the presence of added bromide, the proportions between the densities, that is the gradation, was not under any control, and the negative remained always true

to the subject. The magnitude of the density and with it the contrast, was all that could be altered. But by the use of these intensifiers (except the Chapman Jones) and reducers without exception, these proportions, the gradation, may be manipulated very greatly, and the picture will be no longer a true record of the light and shade. One used to studying photographs will frequently detect it. Their use is in helping already very defective negatives, which however they do not make true, and in pictorial work. They have always to be used with great judgment or they will make matters worse. Their indiscriminate use is to be heartily condemned.

71. **Frilling.**—When dry the gelatine layer adheres to clean glass with very great tenacity. As the film dries it shrinks so that there is usually tension between the film and the glass. If the film becomes exceedingly dry, as it does occasionally in our steam-heated rooms in the winter, the tension becomes so great that something breaks. Quite frequently the film pulls the glass off in small chips which will be found adhering to the gelatine film. When water soaked, however, the union between the glass and the film is weak enough to at times give trouble from the two parting company. It is called *frilling* and commonly takes place around the edges of the plate, but in serious cases may result in loos-

ening the entire film from the glass. It is much more troublesome in summer than in winter, and much more in warm climates than in the cooler ones. It can usually be controlled by using cool solutions and wash water, below 22° C. (75° F.) if possible. Some of the manufacturers have special plates for hot climates in which the gelatine used is harder, that is has a higher melting point and consequently does not soften so much in the warm water. The purpose of the alum which we use regularly in the hypo solution is to harden the gelatine, so avoiding frilling in the later washing and also in the hypo itself. In case one uses plain hypo it will often be necessary to put the plate into a bath of alum after the developer, so that it will not frill too badly in the fixing and washing.

72. **Dust.**—Sometimes on looking over a negative you will find a lot of small clear places of irregular shape and sharp angles which will come out as black spots in the print. These are due to *dust* on the plate during exposure. In the original box the plates are apt to be free of dust, and if the plate holder be kept thoroughly clean there is not likely to be trouble. Besides seeing that the plate holder is clean, it is a wise precaution to dust the plate very lightly with a lintless duster or camel's-hair brush. If the plate be rubbed vigorously the film surface will become electrified and attract

dust strongly—it will be worse than if the plate was left alone. An alternative plan is to blow gently along the film, being very particular not to blow any saliva onto the film, as it will leave a spot.

73. **Air Bells.**—Sometimes one will come on round clear spots, larger than dust marks, or the spots may be irregular with gently curved edges. These are usually due to air bubbles sticking to the film during all or a part of development. Running the tips of the fingers or a soft brush over the film right at the commencement of development, before it has had time to soften, will effectually do away with this trouble, or indeed a little vigorous swishing of the developer back and forth over the plate at the start of development will also serve.

74. **Black Spots.**—Occasionally the film will have small black marks which will print white. These may be foreign particles sticking to the film and they may or may not have caused an extra deposit of silver close to them. It is well to move the developer over the film a few times during development to aid in avoiding such marks, but the most important precaution is to keep all trays clean and solutions clear. Always pour out the solutions gently so as not to disturb any deposit there may be at the bottom of the bottle. Care in keeping everything clean, trays, desk, shelf, plate holders, solutions, will banish such trouble. If the plates

frill during development pieces of the film often become detached and float around in the solution; in which case it is well to keep the developer moving almost continuously. In general it is better to rock the tray only occasionally. In rocking the tray do not lift one end suddenly and then drop it right away again—watch the liquid and you will see that it has not moved. But raise one end of the tray and hold it up for a few seconds, then lower it for a few seconds, and the liquid will have time to flow over the plate. Moving the liquid helps to keep the developer alike all over the plate and so helps to secure even action.

75. **Finger marks** identify themselves readily, and it is best to touch the surface of the film as little as possible, particularly if the skin is moist. When necessary to tell the film side touch only the edges or corners.

76. **Pressure Marks.**—If the sensitive film be subjected to pressure at any time it will deposit silver at these places during development, in other words it will develop. The plate can be marked with a hard metal point just before placing it in the developer, and the marks will develop along with the negative, giving a very convenient way of keeping track of plates. For this reason plates are packed so that the films are held apart by paper along the edges; and for the same reason it is wise

to stack boxes of plates on edge. The same thing is often troublesome with the glossy surfaced developing papers but much less often with the matt surfaced. The deposits in the case of the glossy surfaced papers are right on the surface and may be rubbed off with some absolute alcohol on a clean cloth without injuring the print. Also, strangely

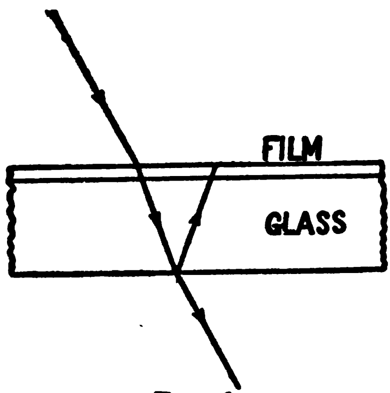


FIG. 16.

enough, the presence of some potassium iodide in the developer will hold back the development of these marks, and while it also holds back the regular development, it does not do so as much.

77. **Halation.**—The spreading of the light from the brightly illuminated parts over into the shadows is called halation. It will hence be most pronounced where the difference in illumination across a narrow line is great. It is particularly noticeable

around windows when taking interiors, and around the fine branches of trees against the sky, the lake, or snow. The fine branches will not appear in the print unless the printing exposure is made too great for the rest of the print. Also in pictures showing the sun or artificial lights the effects show strongly. It is due almost entirely to two causes,[7] (a) internal reflections in the glass, and (b) irradiation. Light reflected from the outer surface of the film strikes the blackened inside of the camera and is mostly absorbed. In the passage of the light from the film to the glass there is but little reflection, on account of the small difference in densities, and the thinness of the film allows but little spreading of the light sideways. But when the light strikes the back surface of the glass, the next medium is air, so that there is a great difference in density and consequently strong reflection. The reflected light strikes the back of the sensitive film usually at some point different from where it entered and so causes a deposit of silver where there should not be such a one in the picture (Fig. 16). It will be evident immediately that it will show most along the edge of a strongly lighted part particularly if the adjoining part is in deep shadow, for instance in the picture of a narrow slit with a lamp behind it. From

[7] Scheffer, *British Jour. of Photo.*, 57, 683 (1910); Goldberg, *Photographic Journal*, 51, 300 (1912).

the way in which the developer has to enter the film, that is from the front surface, it is evident that this halation exposure will not have a good chance of being well developed, as it will be largely at the back of the film; so that when you suspect halation trouble do not develop too long, which will subordinate the halation effect by lessening the contrasts generally and by limiting the development still more of the halation exposure. When possible choose your view point so as to avoid such contrasts. If they are unavoidable, then cover the back of the glass with something which will absorb the light which gets through. Black paper wet with glycerine and rubbed into intimate contact with the glass will do well if the plate is to be used immediately. If not for immediate use a paint of lampblack and mucilage is better but is a messy job to apply; plates can be bought already backed thus. Probably the best arrangement of all is to put the absorbing film in between the gelatine and the glass, so that the light is absorbed before it gets to the glass. This absorbing film can be made of a very slow emulsion (double-coated plates) or of a gelatine film carrying a brown or black dye, which will be bleached in the acid hypo, leaving the plate clear for printing.[8] See Fig. 17, page 144.

[8] Such for example as the "Non-halation Simplex" plates of the Lumiere N. A. Co., Ltd., 11 W. 27th St., New York.

The second cause of the spreading of the light, irradiation, is the scattered reflection from the particles of silver bromide in the emulsion, as in the diagram, thus spreading the light sideways to affect particles which should not be affected if the

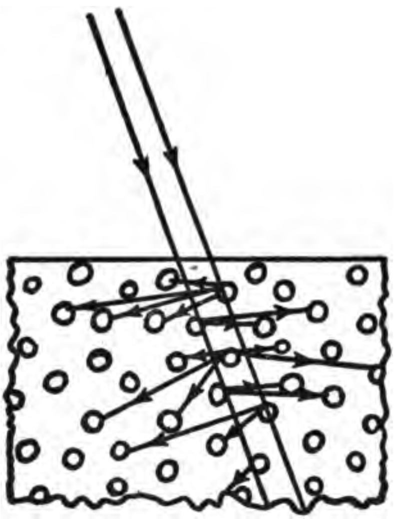


Fig. 18.

picture is to be true geometrically to the subject. This of course will show most distinctly at the edges of a brightly lighted area, for while it is present all over the area it will be uniform and not so easily observed. There is no remedy for it. Fortunately it is not a very serious matter in its effect on the picture. The glass reflection part is a good deal more serious. Halation shows very little in nega-

tives where the sensitive film is carried on the thin celluloid sheet, as in roll-films and film-packs.

78. **"Oyster Shell Markings."**—In the laboratory a number of times now we have run across very peculiar markings on some plates and paper. It consists of wavy somewhat parallel groups of lines often spread over the whole plate. They resemble flow lines in a viscous fluid or the "oyster shell" markings in collodion plates. So far I have not been able to find any satisfactory explanation of their cause or cure.

79. **Stain.**—With most organic developers, and especially with pyro, the gelatine film is stained somewhat during development. With prolonged development in pyro it may be quite pronounced. Sodium sulphite in the developer helps to check it, and the acid along with sodium sulphite in the hypo bath removes a large part but not all. It is of no particular harm if not so dense as to unduly prolong the time of printing.

80. **Bubbles.**—Mention has already been made of the formation of small bubbles right in the gelatine film if the hypo bath is too warm, particularly if the bath is old. The bubbles do not disappear on drying, and if in a negative will show in the print made from it. The same sort of thing shows occasionally in prints, particularly in bromide enlargements, caused apparently by too great changes in

temperature in the different baths, or by too strong hypo bath.

81. **Drying Troubles.**—In addition to the care necessary to remove the deposit which settles from the wash water on the film before putting it up to dry, there are several other things to attend to in the drying of the film. Prevent the settling of dust on the wet surface of the gelatine by setting it on edge to dry, or even set sloping film side down. The film sags slightly during drying so that it is best if it dries at a uniform rate and in one position, which will give the least distortion of the picture and least chance for variations in thickness. The film may be dried somewhat quickly by leaning it film side toward a cold window with a warm room behind. The water will distill rapidly from the film and condense on the window. Of course, if one tries to hasten the drying by warming, the film will melt and the negative be ruined. If the wet plate be immersed in alcohol containing very little water, the water in the film will pass out quickly and almost completely into the alcohol, the film losing its gummy feel and becoming tough and hard. When the alcohol is dried off the film will stand gentle heating to finish the drying, but is still quite easily melted. If the wet film be immersed in a solution of formaldehyde it will harden the gelatine

and render it insoluble in water so that the film may be dried by quite vigorous heating.

For further reading an excellent list and discussion of plate troubles is given by Olaf Bloch in the *Photographic Journal,* 55, 219 (1915).

CHAPTER VI

POSITIVE PROCESSES

In connection with the work in the laboratory it will be advisable to describe a few of the very great many methods of making positives.

82. **Transparencies.**—The most obvious way to make a positive is by exposing another plate either through a lens or by contact, to the light transmitted by a negative. The larger sizes made this way go by the name of transparencies, and when the glass support of the film is translucent milk glass, the effect is in some respects far superior to prints on paper. The total scale, that is the difference between the greatest blackness and the greatest brightness, is many times greater for the plate, which gives them a luminosity and detail in the shadows unapproachable in a print. On the other hand they are more clumsy to view and more bulky to store.

83. **Lantern Slides.**—The small size used in the lantern are the most important transparencies. American slides are made 3¼ inches by 4 inches, while English ones are 3¼ by 3¼, and French are 8

by 10 centimeters—3.54 by 4.72 inches—and general purpose lanterns should be provided with slide carriers to take all these sizes.

All lanterns are made to take the slides long way horizontal and it is hence necessary to make the horizontal lines of the subject run the long way of the slide. For a good slide the grain of the reduced silver should be very fine, which requires a fine-grained emulsion, and these are slow ones. In consequence lantern slide plates are usually especially made slow plates of fine grain, having a thin layer of emulsion on a good grade of glass. The thinness of the layer makes them cheaper and is better since such dense deposits are not required, as in negatives, nor is such latitude in the exposure necessary. Lantern slides are better when they have considerable contrast, and therefore the negatives from which lantern slides are to be made can usually be developed for longer than usual with advantage, particularly where the subject is black and white, as in line drawings or ordinary printing.

It must be observed that the general properties of the gelatine plate, as already described in some detail, are no different in the case of lantern slide plates. Contrast is determined by the subject and the amount of development, so that the maximum density must be controlled by the exposure. The maximum density is always much less than the

thinnest usable negative. The one distinctly new demand is that the clear places must be free from deposit, and hence these places must receive an exposure of about half the inertia. Practically in the laboratory this means the least exposure, which, on a generous amount of development, will give sufficient maximum density. Too long an exposure can not be corrected by quick removal from the developer, but this will always result in a general deposit and in lack of contrast. If the negative has sufficient contrast and the development has not been excessive, a deposit in the clear places means too long an exposure. To avoid a deposit in the clear places a developer giving very little fog is desirable, and on this account the ferrous oxalate developer [1] is without equal. It has the disadvantage that it spoils quickly when exposed to the air and it is best mixed fresh for each plate. It is also necessary to wash out the developer or rather the iron salts in it, by following a rinse under the tap with a soaking for a few minutes in a solution of oxalic acid, as otherwise the clear places may show a deposit of an iron compound which will not wash out in water. The acid in the fixing bath also helps to remove any such deposit. Most other lantern slide developers are loaded with bromide, which

[1] See Manual, Exp. 7.

while suppressing fog also suppresses the lower densities, and so interferes with the gradation. But with the ferrous oxalate the advantage of clear places is accompanied by beautiful full scale gradation so that the extra trouble if any is well repaid.

Lantern slides made by the wet collodion process are still ranked as perhaps the best, as they have very clear high lights and abundant detail. They require however a great deal of care and skill for first class work, and are not often seen today.

84. **Blue Prints.**—Probably the simplest of all the photographic processes for making prints on paper is the "blue print." In it the light-sensitive substance is a salt of iron in the ferric condition. Ferric ammonium citrate is the one frequently used, and the action of light on it is to change the iron over to the ferrous form. Both ferric and ferrous salts are usually only slightly colored so that the image has to be "developed," that is the compound formed by the light has to be changed into an insoluble colored compound. The substance generally used for this purpose is potassium ferricyanide, which forms a deep blue, insoluble compound called Turnbull's Blue with the ferrous salt, while it forms no insoluble compound with the ferric salt. The paper having a suitable surface to carry the colored image is brushed over with a solution of the two salts dissolved in water and dried quickly and thor-

oughly.[3] Exposed to sunlight under a negative, it turns blue showing a visible image; the depth of printing has to be found by trial. If the paper be now dipped in water the ferrous salt formed by the action of the light will react with the potassium ferricyanide, where it has not already done so, changing the ferrous image into Turnbull's Blue, and the extra unused materials will be washed out, thus "fixing" the image. The paper does not keep very well after it is coated, and when it begins to go bad the whites will be tinged with blue. Keeping the paper thoroughly dry retards the deterioration very much, and, conversely, dampness ruins it quickly. It is advisable but not at all necessary that the coating should be uniform, as quite streaky papers will give good prints if there is sufficient supply of the salts at all places, so that the light will have plenty to act upon, and the excess disappears in the washing. Not all papers are suitable for coating; a tough paper with a good surface is required, and often it will pay to size it by coating with albumen or gelatine.

85. **Printing Out Paper (P. O. P.).**—It is also called gelatino-chloride paper. This is made by coating paper with a layer of gelatine in which is present some soluble chloride like sodium chloride. When dry this is floated on a solution of silver ni-

[3] See Manual, Exp. 16.

trate, when the silver salt reacts with the chloride to give the insoluble silver chloride, and the other compounds present at first or formed are removed by washing. The gelatine may be partially or entirely replaced by albumen, giving the albumeno-chloride papers. The treatment in all cases is very much alike.[8] They all require sunlight for printing and give a red image which fades out materially in the fixing; if the hypo is used too strong the bleaching is serious. The red color is usually not considered a pleasing tone, and there is some doubt as to the permanence of the red image, but if it is made with care, especially by the use of fresh hypo and thorough washing, it is probably permanent. To change the color and to add permanence it is customary to exchange the silver forming the image for gold or less frequently for platinum. Simple contact between the silver in the image and the gold or platinum salt in solution is sufficient to cause them to exchange places, the silver going into solution and the gold changing from the compound to metallic gold, or metallic platinum in case a platinum salt is used. The image in either case is very permanent. With gold the color or tone may be varied through red to purple to a good black. Most photographers' proofs used to be made on this kind of paper, but of a very poor grade and not very

[8] See Manual, Exp. 17.

suitable for toning. "Solio" is one of the best known makes of this paper.

In the past photo-engravers much preferred prints on this paper from which to make cuts. They liked the color, the glossy surface, and the wealth of detail. Opinion is changing somewhat, and prints on glossy developing paper, where the image has a green tone, are now often asked for. Photographers generally still rank prints on printing out paper ahead of prints on developing paper, but the former requires more time and labor, so that they have gone largely out of general use.

86. **Developing Paper.**—At the present time this is by all means the most popular printing method both among amateurs and professionals. Its popularity is justified by its ease and certainty of working, by the permanence of the prints, and by the great variety of surface and of ability to render contrast which may be obtained. The paper is coated with an emulsion which is very similar to the plate emulsions except that it is much finer grained and slower. Besides this it usually has preservatives added to improve its keeping qualities, and good prints can often be made on paper years old. Two distinct grades are on the market, one called "bromide paper," designed for enlarging work and therefore having a fast emulsion, the other slower, designed for contact printing. By

the choice of the paper on which either is coated and by manipulation of the emulsions, the surface of the dry print may be varied from a very brilliant gloss gradually to a very coarse pebble or matt. The choice of the different surfaces is determined by the taste of the worker and the character of the picture; where great detail is desired the glossy surfaces are best, and where less detail is desired, as in portraits, some one of the matt surfaces is to be preferred. It is worthy of note also that the amount of contrast which the paper can render is greater in the case of the glossy surface. Besides this range of surfaces, most makers turn out several different grades of paper, which differ in their ability to render contrast, some designed to give strong contrast for use with flat negatives or where harsh prints are desired, the others grading over to a paper intended to lessen the contrasts in too harsh negatives. Skillful use of these varieties gives the worker great command over the character of the print.

Ever since Hurter and Driffield's work with plates efforts have been made to systematize the properties of developing paper. This has finally been accomplished [4] and the results are of great interest to the user of the paper as well as to the manufacturer. Since prints are observed by reflected light

[4] Jones, Nutting & Mees, *British Journal*, 62, 9 (1915).

while negatives are used always with transmitted light, the "density" of the image will have a somewhat different meaning in the two cases. The curves are very similar to the plate curves and the conclusions with regard to exposure and development are also very similar. As a rule the papers develop very rapidly, so that the value of gamma quickly reaches a maximum; with the usual bromided developers the further progress of development simply shifts the curve parallel to itself. The contrast of the paper is fixed by the slope of this line and its projection on the exposure axis. Usually as this slope increases with different papers the latitude of the paper decreases. As with plates a portion of the bent ends of the characteristic curve is used in practice, and the projection of these straight and curved parts on the exposure axis is called the *"total scale."* As would be expected the total scale of hard papers is much smaller than that of soft papers. On account of the rapidity of development it is not possible to control the contrast materially by varying the development. The only control is by choice of the grade of paper.

In most cases the printing method is at its best only with a particular amount of contrast in the negative. In fact such an amount that the difference in the printing exposures between the densest and the thinnest parts of the negative should be

such that when the thinnest part exposes the paper for its maximum density, the exposure under the dense part will be just not sufficient to show grayness. That is the amount of contrast in the negative should be such as to give a series of exposures to the print as nearly equal as possible to the full scale of the paper. Otherwise part of the detail in the negative will be lost—a very common case—or use will not be made of the full capabilities of the paper. The latitude of a plate always exceeds the variation in the light intensities in the ordinary subject so that the plate can render truthfully the full scale in the subject. But with printing papers this is usually not so, the total scale of the paper being too short. In such cases one can reduce the gamma of the negative to less than unity by lessening its development, or sacrifice detail at one or other end of the scale. To illustrate, by lengthening the printing exposure with an ordinary negative the clouds may usually be shown on an ordinary print, but then the whole foreground will be black; while if the printing exposure be short enough to show the detail in the foreground, then the sky will print white. But if the negative had been developed for a shorter time, thus lessening the amount of contrast, it may be reduced to the total scale of the paper, so that the sky and foreground detail will both appear in the same print. It may

also be possible to select a paper with a greater total scale, and so accomplish the same end.

A developer such as the ferrous oxalate, or metol, or hydrochinon, etc., which will not stain the paper is required. An acid hypo will aid in avoiding any stain from the developer, and the hardening agent, alum, will aid in avoiding trouble in any subsequent treatment of the print. Care is required in the use of the hypo bath, that it be kept clean and reasonably fresh, and that none of it be allowed to get into the developer. Yellow stains in the print will be traced most often to the presence of a small quantity of hypo in the developer; these stains often do not show or are not noticed till the batch of prints is dry, so that the trouble escapes notice at the time when it could be remedied by the use of fresh developer. It is one of the cases where care and cleanliness bring an ample reward. Refer to the Manual, Exp. 4, for further laboratory details.

The color of the image is ordinarily a shade of gray or black. If the developer contains a large proportion of soluble bromide, say potassium bromide, the image will have a marked green shade. If the ordinary metol-hydrochinon developer is made with little or no carbonate, the image will be a shade of brown with lessened contrasts. Besides these shades the color of the image in the finished picture may be changed to one of many other colors

by the use of suitable reagents, and of these methods we will consider only one.

87. This process called *"Sulphide toning"*[5] changes the silver in the image into silver sulphide, which has a brown color when divided, as it is in the print. It is not feasible to change the metallic silver directly into the sulphide, so that the process has to be carried on in two steps, first the change of the metallic silver into some insoluble silver salt, usually the bromide, and second the change of this salt into the sulphide. The well-washed print is first immersed in a solution of potassium ferricyanide and potassium bromide. The ferricyanide attacks the silver forming the potassium silver ferrocyanide, thus,

$$Ag_2 + 2K_3Fe(CN)_6 = K_4Fe(CN)_6 + K_2Ag_2Fe(CN)_6$$

and the potassium bromide changes this over to silver bromide on account of the much greater insolubility of the latter, thus:

$$K_2Ag_2Fe(CN)_6 + 2KBr = K_4Fe(CN)_6 + 2AgBr$$

The silver bromide is a pale yellow so that the result of this is to change the black silver image to an almost invisible one. The bleached print has then to be thoroughly washed to free it from all of these substances except the silver bromide, which is too

[5] Manual, Exp. 19.

insoluble to wash out. The second step in the process is to immerse the washed bleached print in a solution of some soluble sulphide, such as sodium sulphide, Na_2S, when the silver bromide will be changed into the brown silver sulphide, thus:

$$Na_2S + 2AgBr = Ag_2S + 2NaBr$$

this change also being induced by the greater insolubility of silver sulphide than of silver bromide. Shades between brown and black may be obtained by partially developing the bleached image in any paper developer, and then changing the remaining silver bromide into silver sulphide, as above.

88. Platinotype.—This is a process which is closely allied to the Blue Print Process, and is often referred to as platinum paper. In this connection it is well to note that a number of the commercial papers described as platinum papers are only imitations of them, the paper being really a slightly modified developing paper. Platinum is an exceedingly expensive metal, three or four times the cost of gold, and it takes enough of it to make a satisfactory paper that it is a very important item, so that there is a great incentive to substitute some less expensive material. The modified developing paper is a very good imitation. The light sensitive substance in real platinum paper is a ferric salt, usually ferric oxalate, $Fe_2(C_2O_4)_3$, which by the

action of the light changes over to ferrous oxalate. The ferric salt is mixed with a salt of platinum, usually platinic chloride $PtCl_3$, and the solution coated on paper exactly as with blue print paper. The surface of the paper is often not suitable, in which case it has to be coated with something which will hold the particles of platinum forming the finished image. The coating may be done with various substances, as starch, or gelatine, by floating the paper on the solution of one of these and then drying it. After sensitizing the paper has to be dried as quickly as possible, and to have it keep good for even a few days it must be kept exceedingly dry.

The commercial makers have some tricks for aiding the keeping qualities, but they all have to be kept dry also. For this purpose the paper is usually kept in closed boxes, where there is also placed some water-absorbing agent, such as calcium chloride. In spite of all care the paper will only keep a few weeks, after which it will have a deposit in the clear parts of the image, that is, show fog. It has to be printed in direct sunlight, and the image shows only slightly, so that the progress of printing has to be followed by some kind of exposure meter, such for example, as a piece of solio under another negative but exposed to the same sunlight. It is much better to use a constant light source, as the arc or a high-

power tungsten lamp, when the time of exposure gives a direct measure of the progress of printing. After exposure the paper is developed by floating face downward on a solution of potassium oxalate in which the iron salts are soluble. In solution ferrous salts quickly reduce the platinum salt to metallic platinum with the simultaneous formation of ferric salt again. This reaction takes place only where the ferrous salt has been formed, so that the ferrous image is changed into a metallic platinum image. The print must be washed carefully to rid it of all iron salts. Such prints are very permanent, but they can hardly be more permanent than the paper support, and a good developing paper is as permanent as that. This paper lends itself readily to a lot of different surfaces and grains, and particularly readily to the production of pictures in which the fine details are run together to give large light and shade effects—what are often referred to as "artistic" prints. In special cases there are advantages to be gained by this sacrifice of detail, but in a great many of the pictures one sees the gain is very doubtful.[6]

89. **Carbon Printing.**—In this process we come back to the use of gelatine, but this time it is the light sensitive material itself. It is based upon the

[6] For a more extended discussion of Platinotype see *Phot. Miniature* No. 7.

property that if it be bathed in a solution of a salt of chromic acid, like potassium chromate or ammonium chromate, and then dried, the gelatine remains soluble in warm water, but if while still dry it be exposed to light, the gelatine becomes insoluble in warm water. In consequence a film of gelatine sensitized with the chromate may be exposed to sunlight under a negative, and the parts left soluble can be washed away with warm water, leaving a positive. The gelatine film may be colored with dyes or carbon (lamp black) so that the resulting print can be any tone desired and the same tone may be duplicated any number of times whenever desired. It will be evident from the way the exposure is made that the insoluble image will be on the surface of the gelatine film and extending down into the unaffected gelatine and probably in no places extending right through to the paper support. So that when treated with warm water the whole image will float off. To avoid this it is necessary to support the image on the exposed side by transferring it to a support in contact with this surface. This is very readily accomplished by bringing the wet image surface in contact with a wet, hardened, gelatine surface, and when the excess of water is pressed out they will adhere quite sufficiently to preserve the image while the original support is soaked off with warm water and then the

remaining soluble gelatine washed away. This transfer reverses the image, making it right left-handed, and to bring it back to agreement with the subject it requires another transfer. In some cases, as portraits for example, this reversal does no harm but in case it is necessary it is readily done. If the surface to which the print is first transferred be previously rubbed over with a small quantity of beeswax dissolved in turpentine, the developed print after drying will leave it usually spontaneously; the final support, usually a soft gelatine surface, has to be rubbed into contact with the developed print while all are still wet, and all allowed to dry in contact; when dry the temporary support splits off easily.

The tissue as supplied by the dealers [7] is simply a thin layer of colored gelatine spread over a strong paper, and in this condition it will usually keep for years. When wanted it has to be sensitized by bathing in the solution of the chromic salt, or by brushing the solution over the surface of the gelatine, or the most convenient way is to brush over the surface an alcoholic solution of ammonium chromate, which dries off quickly, and the tissue is

[7] Autotype supplies for all kinds of carbon printing may be obtained from George Murphy, Inc., 57 East 9th St., New York, who also can supply several good books. Tissue on a transparent celluloid support may be obtained from the *Neue Photographische Gesellschaft*, Berlin, Steglitz.

ready for exposing in an hour or two. The film must be thoroughly dried and then kept as dry as possible or it will fog in a few days or even hours. It is best kept in a closed box in the presence of calcium chloride. Even with all precautions it only keeps in good condition for a week or two, so that it has to be sensitized when needed.

As with platinotype paper, the progress of printing cannot be seen, as the image is almost invisible, and it has therefore to be followed with some kind of an exposure meter when the source of light is a variable one like sunlight. If a steady source, like a good arc lamp, be used a few trials will determine the time required. The tissue can also be bought where the gelatine layer is carried on a thin, transparent celluloid support and the printing can be done through the support, thus saving the trouble of the first transfer.

The process requires more labor and skill than the ordinary developing paper process, but is not difficult enough to be beyond the reach of any ordinary worker. The method is exceedingly flexible as to the rendering of fine detail or large fuzzy effects depending on the treatment in the warm water, and as to the tone of the finished print. It can be used to advantage in lantern-slide-making for the same reasons, and has a very important ap-

plication in the making of pictures in their natural colors.

90. **Photo-engraving.**—There are many printing press methods which come naturally under this head. But the great majority of newspaper, magazine, and book illustrations are made by methods of which the half-tone zinc etching may be taken as a type. The first step is to make a negative of the subject to be copied. In this, one detail is different from the ordinary process. At a short but definite distance in front of the plate in the camera is placed a line screen made of two sets of parallel lines, the sets being at right angles to each other, and in each set the width of the opaque lines and the clear places are about equal. This breaks up the light image into a series of dots, but on account of the separation of the line screen and plate, the dot on the plate is brightest at the center and falls off gradually instead of ending sharply. The result of this in the negative is to make the dots large in the brightly illuminated parts and small in the dark places. For the best effect these dots have to be very opaque and clearly marked so that the negative has usually been made by the wet collodion process, which gives very clear shadows and allows readily of very great intensification.

A print is made from this negative as in the carbon process, only using a very thin layer of bi-

chromated fish-glue supported on a polished zinc plate, and the exposure is made long enough that the insolubility extends right through to the metal. This is developed in warm water, dried, and the plate heated to almost char the fish-glue, which makes it very hard and also insoluble in the acid bath into which the plate is next dipped. Where exposed the zinc is eaten away and special precautions have to be taken to prevent the acid eating under the edges of the glue. The hardened glue is left on as it forms a good wearing surface, the plate dried, inked by passing an inky roller over it, and the inked plate pressed against paper. The unetched parts of the surface will transfer ink to the paper, while the etched parts will not touch it. The unetched parts correspond to insoluble glue, these to clear places in the negative, these to dark places in the original subject, so that dark places in the original subject are represented by inky places in the print. Where the light is strong in the image, the silver dots in the negative spread out and overlap, leaving, therefore, clear dots on a black ground; and where the light in the image is weak, the silver dots in the negative stay small, appearing, therefore, as black dots on a clear ground. In the positive image in glue and in ink, the clear and black places have been reversed, but the same general character of dots and background remains, the

bright parts of the subject being represented in the ink print by small black dots on a white ground, and the dark parts by small white spots on a black ground. The grays are represented by intermediate conditions of dots and ground, and the ability to thus render the half-tones is responsible for the name and largely responsible also for the beauty of the process. The number of these dots is determined by the spacing in the line screen used in front of the negative, and the screens in use vary from 50 to 400 lines per inch. The best screen to use depends upon the character of the subject, the surface of the paper used for the printing, and the mechanical method of making the ink impression.

CHAPTER VII

LENSES

91. Pinhole Images.—It is not necessary to have a lens in order to take a picture on a sensitive plate. If the ordinary lens of a camera be replaced by a very fine hole, like that made by a very fine needle

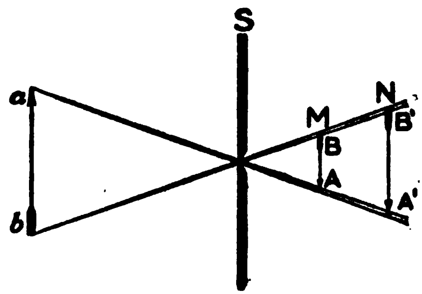


FIG. 19.

in a piece of tinfoil, there will be an image formed on the plate. The way in which it is formed is shown in Fig. 19. Light from one point in the field of view can get at only one point on the plate, so that the light forms an image, inverted and right left-handed, as in the case of the lens image. The sharpness of this image depends first of all on the size of the pinhole and then on the distance of the

plate from the pinhole. At first sight it would look as if reducing the size of this hole would sharpen the image no matter how small the hole already was, but another property of light which we do not ordinarily notice enters to upset this prediction. Along the edge of a sharp shadow light does not travel in perfectly straight lines but bends into the shadow very slightly, so slightly in fact that it is very difficult to detect. Moreover, as it spreads, light from the two sides of the pinhole have different distances to travel to reach a point in the image out of the direct line with the pinhole and source of the light, so that the two waves as they reach this point may be out of phase, that is one wave may be a crest and the other a trough, and the addition of the two will result in no wave. This takes place in such a way around the central bright spot that there will be formed a series of bright and dark rings, Fig. 20, which is a photograph of a small bright source of light taken through a pinhole. The central bright spot is much the brighter, and, going outward, the rings decrease rapidly in brightness till they disappear.[1]

As the pinhole is made smaller than a certain size the central image becomes larger and

[1] See, for example, M. E. Hufford, *Physical Rev.*, second series, 3, 242 (1914).

also the proportion of the total light which is in the central image becomes smaller, so that the image of the point does not become smaller but really larger when the pinhole has passed a certain size at which the definition is best. The size of the image is directly proportional to the distance of the plate from the pinhole, as is easily seen from the

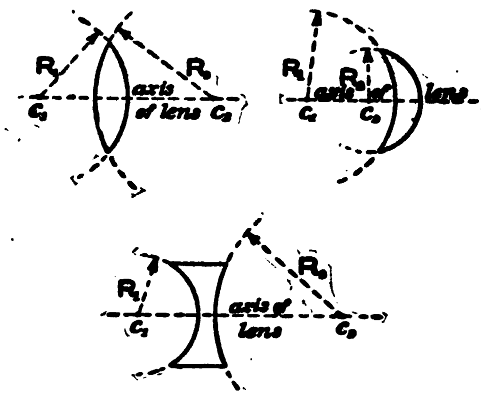


FIG. 22.

geometry in Fig. 19. Compared in brightness with the image formed by a lens, this image is exceedingly faint, and the exposure required may be hundreds or thousands of times that with the lens. But it has some marked advantages over an image formed by a lens; the whole picture is in focus at once, foreground and background, Fig. 21; page 146; it cannot be got out of focus, and the

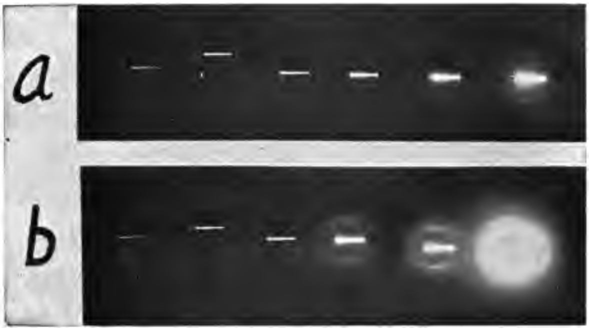


FIG. 17. Photographs of a narrow slit illuminated from behind with an arc light. Each image from left to right received 5 times the exposure of the preceding one. Series b was taken on an ordinary plate, and series a on a double coated plate. See Art. 77.

FIG. 20. The image of a small very bright source of light taken through an almost perfectly round pinhole on a plate about a meter away from the pinhole. It is reproduced the same size. See Art. 91.

geometric correspondence between image and object is perfect.[2]

92. **A lens** may be described as a transparent medium bounded by regularly curved surfaces, or some of the surfaces may be planes. The curved surfaces are almost invariably spherical; some few exceedingly expensive telescopic lenses are sometimes varied from spherical by tedious hand polishing, taking years to do. All photographic lens surfaces are plane or spherical, see Fig. 22. This allows of several different types of lenses, Fig. 23, falling into two classes, (a) one spoken of as converging lenses because they will bring a parallel

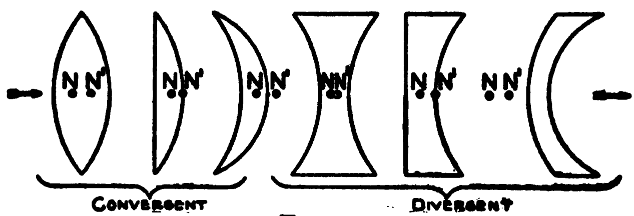


FIG. 23.

beam of light, like sunlight, to a focus, and (b) the other spoken of as diverging lenses because a beam of light like sunlight will be spread out by passage through the lens so that it will appear as if it spread from a point on the side of the lens on which the light came. These two points are both called

[2] See "Pinhole Photography," *Photominiature*, No. 27.

foci, the first a real focus and the second an imaginary or virtual focus. The straight line through the centers of the spheres of which the lens surfaces are a part, is called the axis of the lens. If one of the lens surfaces is a plane, the axis meets it perpendicularly while it also passes through the center of the sphere of which the other surface is a part.

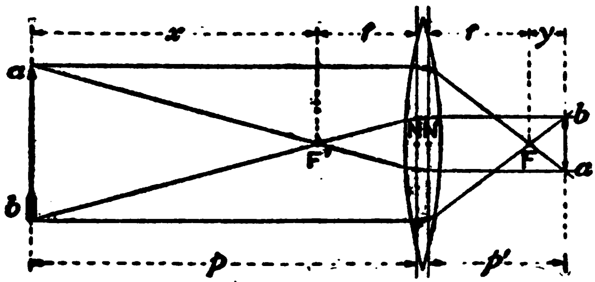


FIG. 24.

When a lens is formed of more than one piece of glass, as with the majority of photographic lenses, the centers of all the spheres should lie on the one line; a lens otherwise perfect may be very much impaired in definition of image if the makers of the mount have not been careful to have this condition filled.

93. **Images.**—The method of formation of an image by a converging lens is shown in diagram in Fig. 24. If the object is very distant and on the principal axis the light from it will be practically parallel as it strikes the lens and it will be

FIG. 21. Pinhole image. Taken through a pinhole about ⅓ mm diameter on a plate 5 inches away by an exposure of 1 minute. Reproduced the same size. See Art. 91.

FIG. 28. The three photographs are of a book set on a slight slope. In 28 the focal length of the lens was 5 inches and the center of the book was 15 inches from the lens.

brought to a focus at a point which is called the principal focus, see Fig. 25. The distance of this point from the lens is called the focal length of the

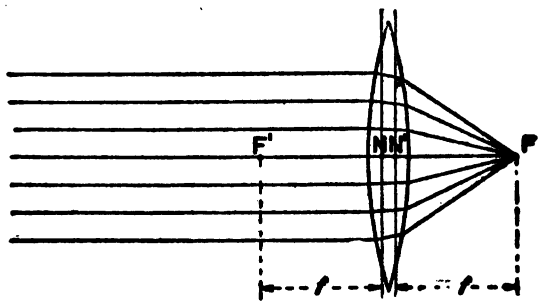


FIG. 25.

lens. In this connection the two points N and N′ are important, see Fig. 24. They are called nodal points and are so placed that rays of light entering

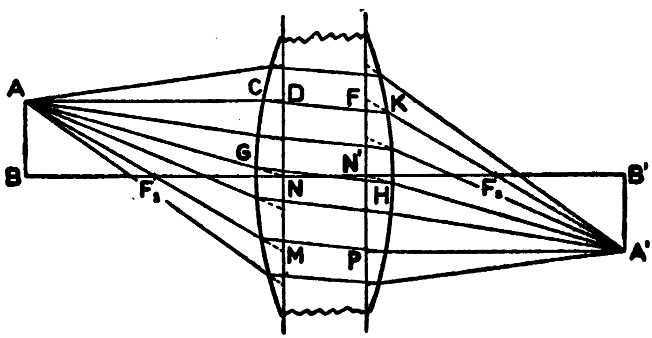
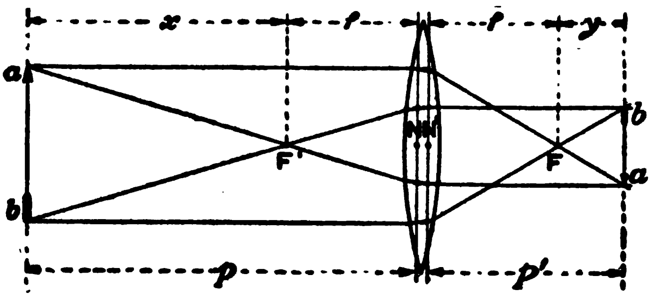


FIG. 26.

one from its side of the lens will appear to have come from the other as it emerges from the lens.

They are more useful and accurate than the older treatment using the optical center.

They have another property, shown in Figs. 24 and 26; it is that planes cutting the axis perpen-



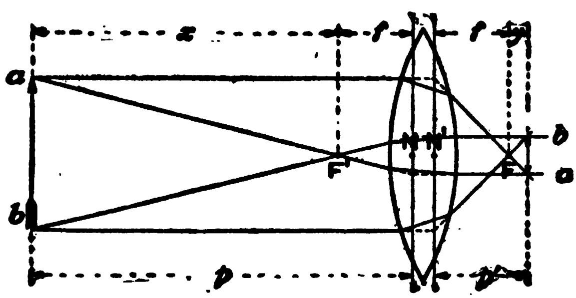


FIG. 27.

dicularly at the points N and N′ are so placed that rays appearing to strike a point in the forward plane, leave the lens as if they came from a point in the rear plane immediately back of the first point. This makes it very simple to follow the actual path of a ray through the lens and therefore

also simplifies the construction of lens diagrams showing the formation of images. In measuring the focal length of a lens, the distance is measured from the nearest nodal point to the image of a very distant object, the sun for example. These points are of the greatest value in the calculating and designing of lenses. One other property deserves mention; that is if the lens be rotated about either of these points the image will not move. It is about one of these points that the panoramic camera lens is made to rotate in order to get the picture covering at least 180′. These points apply not only to lenses formed of one piece of glass but also to lenses formed of a number of pieces and whether they are in contact or not.

94. **Size of Image.**—From the diagram in Fig. 24, it is very simple geometry to show that the size of the image is to the size of the object as their respective distances from the lens, or more strictly from the nodal points. The distance of the image from the lens, for a given object distance, is determined by the focal length of the lens. Thus if one has to take a picture of an object from a fixed distance, the size of the picture, that is of the image, can be varied by choosing lenses of different focal lengths, the longer the focal length the larger the image, see Fig. 27, the size of the image and its

distance from the lens being in all cases proportional. For the same reasons the focal lengths of lenses made for use with large plates are in general longer than those for use with small plates. A choice of focal length is an advantage in another case, namely where to get the desired size of picture, the object has to be brought close to the lens, which results in bad perspective and in distortion, the near parts of the object looking too large; Art. 139 and Fig. 28. A longer focus lens enables one to move the camera farther away from the object with a corresponding improvement in the character of picture.

95. **Defects in Images Formed by Lenses.—Aberrations.**—If one examines the image formed by a lens consisting of one piece of glass with spherical surfaces, one will find some serious defects, that is to say a serious lack of correspondence between the geometrical form of the object and of the image. For instance fine lines in the object will be represented by blurred lines in the image, that is the image is not sharp, no matter how carefully one focuses. The middle of the image will be in better focus than the edges, and if one examines carefully it will be found that every bright object is fringed with color in the image. It will be necessary to discuss at least seven different things which go to make

a lens image an imperfect copy of the original. They are

Spherical aberration and coma,
Chromatic aberration,
Curvature of field,
Astigmatism,
Distortion,
Flare,
Unequal illumination.

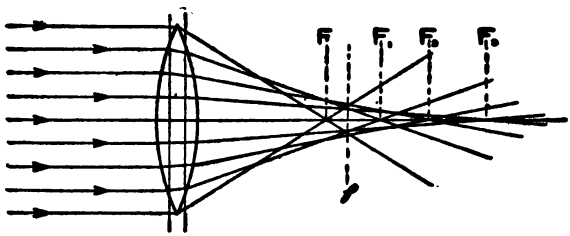


FIG. 29.

96. The most serious, since the most difficult to correct, is *spherical aberration.* It causes a blurring of the image and the explanation is best made in terms of the diagram Fig. 29. The rays of light near the edge of the lens are brought to a focus usually nearer to the lens than the rays passing near the center, the result being a blurred focal point; of course, the same thing will happen with the image of every point in the object. If one puts a diaphragm in front of the lens so as to cut off the marginal rays the image will become clearer, the lines sharper and the image will seem to move farther from the lens, at least the clearest place

will be farther from the lens. But it helps the definition, and that is the reason one uses a small diaphragm when possible. The diaphragm is best placed some distance from the lens, as will be discussed more in detail under distortion. A form of lens in which spherical aberration is small is one

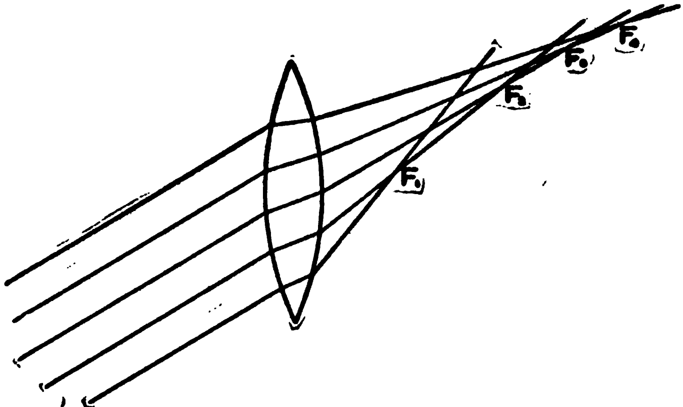


FIG. 30.

with concentric spherical surfaces, and a number of fine lenses are on this plan. A deep meniscus lens, see Fig. 23 third lens, used with the hollow surface toward the object has also a relatively small amount of spherical aberration.

97. **Coma.**—If rays coming from a distant object placed on the axis of the lens, form such a blurred image, it will be evident also that moving the point along the axis toward the lens will not improve the definition or indeed change it materi-

ally. If the point from which the rays come is moved off the axis, the definition is made even worse, see Fig. 30, and in this case it has received the special name of *"coma."* In the case of lenses for use in telescopes coma will not matter since the object is always on the axis or very nearly so, and in this case the spherical aberration correction becomes a much simpler matter and can be made with a high degree of perfection. But in photographic lenses, where both should be corrected, approximate corrections have to suffice. The amount of spherical aberration in a lens depends upon the particular curves used to form the lens surfaces and upon which of the two curves faces the incident light. Turning a lens with the other face to the incident light often changes the amount of spherical aberration quite materially. The amount does not depend, except as it affects the curves, upon the differences in thickness at the center and at the edges of the lens. The correction for chromatic aberration does depend upon this so that one correction need not interfere with the other.

98. **Chromatic aberration** is a very serious fault with simple lenses, that is lenses formed of one piece of glass, and all photographic lenses worthy of the name are formed of at least two pieces of glass designed to correct this fault, and are called "achromatic lenses." The difficulty arises from the

fact that the different colors of light are not brought to the same focus by the simple lens, but the violet rays which are refracted most are brought to a focus nearer to the lens than the red rays, Fig. 31. The foci for the other colors fall in between. With a simple lens the difference may amount to

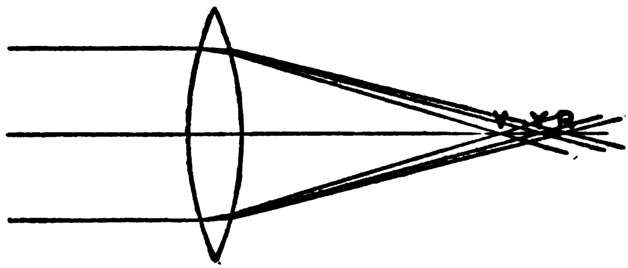


FIG. 31.

1/30 of the focal length of the lens, and is particularly bad in photography because the focusing is done largely with the yellow light, while the photograph is taken largely by the blue, so that in the photograph the object will very generally be out of focus. It affects not only the sharpness but since the size of the image depends on the distance from the lens which is fixed by the focal length, the images formed by the different colors of light will be of different sizes.

99. **Achromatism.**—The approximate correction is not a very difficult matter. Glasses differ very markedly in the amount of separation of the focus

for the different colors, that is in what is called their dispersion. A flint glass lens has a much greater dispersion than a crown glass lens of the same focal length, see Fig. 32. It will be a simple matter to make a diverging flint glass lens whose dispersion will be equal in amount but oppo-

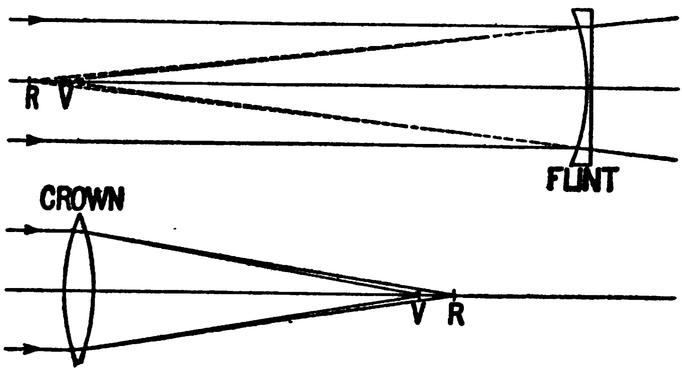


Fig. 32.

site in kind to that of a converging crown glass lens. If light is passed through one right after the other the dispersion will be approximately corrected, but the convergency of the crown glass lens will more than offset the divergency of the flint and the combination lens will be a converging one though of less convergency than the crown glass lens alone. Such a lens is called an achromatic lens or simply an achromat, see Fig. 33.

This is, however, only an approximate correction. If the series of points at which the different colors

are focused in the two lenses, are placed side by side, see Fig. 34, it will be immediately apparent that if any two of these color foci are made to

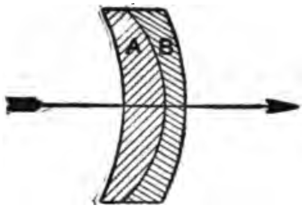


FIG. 33.

match, as for example in the violet and red in the figure, then the others will not match exactly but only approximately. Lenses can be made easily so that the dispersion of any pair of colors will be

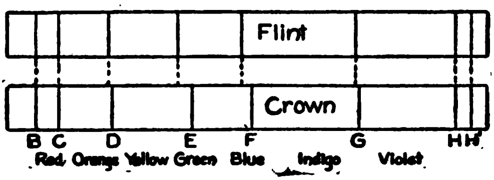


FIG. 34.

equal and opposite to that with the same pair of colors with the other lens, and then the foci for these two colors will be the same in the composite lens and the foci for the other colors will be nearly the same. The pair chosen for exact matching depends on the use to which the lens is to be put. In lenses for visual work, like in microscopes, etc.,

the green and the orange are usually chosen because these along with the yellow, which will fall very close to them, are the colors which affect the retina of the eye most strongly. For photographic work another pair is better, namely the violet and the yellow, the yellow being about midway among the colors used for focusing and the violet being about midway among those which actually take the picture when using the ordinary silver bromide plates. This makes a fairly satisfactory lens for all ordinary work, and is the arrangement used in all except the high-priced lenses. But in case one is doing three color work, this will not be sufficient correction since the pictures, one in each of the three colors, must agree exactly in size and sharpness. The use of a third lens of another kind of glass, all three lenses cemented together, will enable one to make three colors fall exactly at the same focus, instead of two as with two glasses; these three colors which match should be those used in three color work, usually red, green, and blue. When three colors agree in foci exactly, the remaining colors will of necessity focus so close to the same point, that the lens is practically perfectly corrected in this respect and may be used for all kinds of fine work. Another plan, and that used in many or most modern lenses since it requires fewer pieces of glass, applies only to lenses of the

doublet type, that is lenses formed of two groups of pieces of glass with the diaphragm between the groups. A simple achromat of two pieces of glass, as described above, Fig. 34, will make two colors come to the same focus, and the lack of focusing of the rest, called secondary dispersion, results from either too great or too small correction in these colors by the correcting divergent lens. One pair of glasses forming one group of the doublet can be chosen so that the correction for these neglected colors will be too great, and the other pair for the other group so that the correction will not be great enough, and the result will be to make the correction for these neglected colors almost exactly right. A great variety of different kinds of glass is now made by the glass makers, particularly by Schott of Jena, and it is a comparatively simple matter to choose glasses from their lists which will have the properties needed for the matching as described above. Lenses corrected for three colors are called "apochromatic." In lenses formed of groups of pieces of glass, it is necessary that each cemented group should be achromatized separately for the main correction at least, so that the lens formed of these groups may have the same focal lengths for the different colors and at the same time form images of the same size.

100. For most work it is desired that the image be

formed on a plane surface and be in focus all over it at once. With a simple lens this is not the case, but usually the marginal focus is shorter than the central, that is to say the image is curved concave toward the lens. Such a condition is described as *"curvature of field."* When this is the case with a lens, it is best usually to focus for some point about

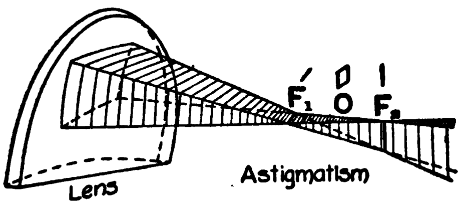


FIG. 35.

half way out to the edge of the plate, so that the middle and edges will be about equally out of focus and the intermediate parts will be clear. This will avoid any part being too badly out of focus unless the curvature is very great. High-priced lenses are corrected for this defect by the addition of another component (piece of glass) to the set of glasses.

101. If an object made up of cross lines be focused way out at one side of the plate it will often happen that one group of lines will be in better focus than the other group at right angles to the first group. This is called *astigmatism.* The cause of the trouble is the unequal focal length in the two planes as represented in the diagram, Fig.

35. It is a serious defect in all cheap lenses and in the more expensive lenses is difficult to correct. Lenses in which astigmatism, spherical and chromatic aberration are corrected will usually be composed of three glasses for each group, and the group is usually duplicated, forming a doublet lens, the most common photographic type.

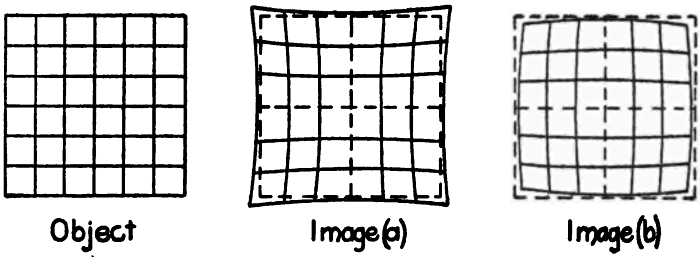


FIG. 36.

102. If an image of a set of lines crossing at right angles be formed by a single glass lens, it will be easily seen that the lines in the image are not straight, although they are in the object, see Fig. 36. This lack of correspondence in shape between the object and the image is called *Distortion.* When a simple lens is used without any diaphragm, that is at what is called full aperture, it usually shows distortion which is directly dependent on the spherical aberration of the lens. The use of a diaphragm by limiting the rays going to any point in the image, to a restricted area of the

lens, modifies the distortion greatly. In case the distortion is barrel-shaped, as in Fig. 36 (a), a diaphragm in front of the lens exaggerates it greatly, while pin cushion distortion, Fig. 36 (b), is exaggerated by the diaphragm behind the lens. The size as well as the shape of the image is affected as will be seen readily in Fig. 37.

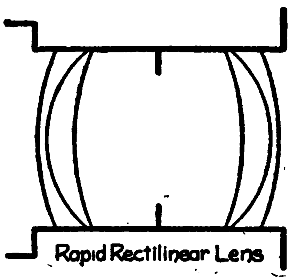


FIG. 38.

The obvious remedy is to use two lenses placed on opposite sides of the diaphragm so that their distortions will be of opposite kinds, and so neutralize each other. Largely on this account most photographic lenses are of this doublet pattern. The rapid rectilinear is the commonest lens of this type, Fig. 38. It has two simple achromatic lenses with similar faces toward the diaphragm and separated by a short distance with the diaphragm half-way between them.

103. If one had a lens formed of several pieces of glass, especially if they are not cemented together,

and used it with a very small diaphragm, sometimes there will be formed in the picture lights and shades which have nothing to do with the object pictured. The commonest case is a bright spot right at the center of the picture. It is still more likely to occur

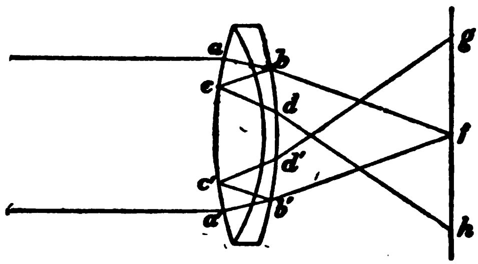


FIG. 39.

if the sunlight falls on the lens. It is described as *"Flare"* or *"Ghost"* and is due to reflections of light back and forth between the different surfaces of the lens, ultimately some of it getting to the plate, but by the time it does so it will be far from the place it rightly occupies in the picture, see Fig. 39. No good lens should show it in any ordinary work.

The proportion of the light approaching the lens which actually appears in the expected place in the image lies,[8] between 55 and 92%, so that it varies materially in different lenses, and the loss in some lenses is serious. The loss is due to reflection at the various surfaces and to absorption in the

[8] P. G. Nutting, *Astrophysical Journal*, 40, 33 (1914).

glass. Poor polish of the surfaces and bubbles in the glass also increase the loss.

104. The remaining difficulty is that of *unequal illumination,* and Fig. 40 will show some of the reasons for it. The width of the pencil of light going to different parts of the plate is cut down by

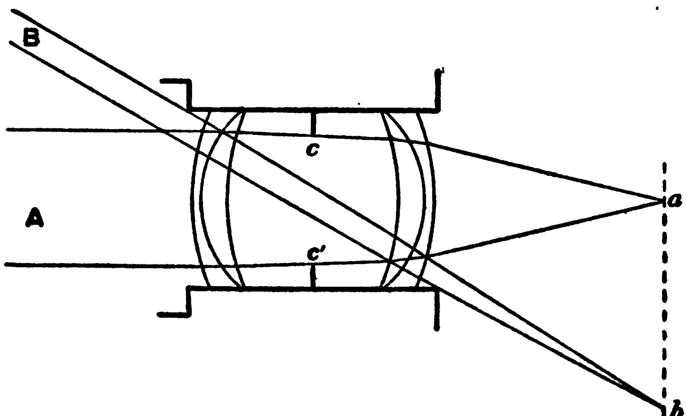


FIG. 40.

the lens barrel when it makes an angle with the axis. For this reason, lenses which are made to cover a large plate as compared with their focal lengths, that is, lenses taking in a big angle of view, are made with the lens barrel as short as possible. Even in case the beam is not cut down by the barrel, it will be cut by the diaphragm not presenting the same area in its direction as it does along the axis. Added to this, the light has to travel a greater distance to the plate, and therefore has to cover a

greater area; moreover, it will strike the plate at an angle not a right angle, so that again it will have a greater surface to cover. All these things

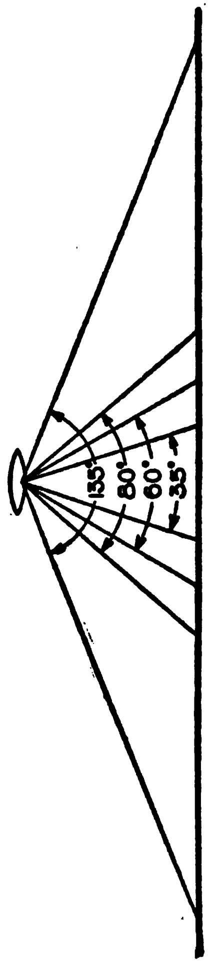


FIG. 41.

add to make it quite a serious matter to get sufficiently equal lighting towards the sides of the plate. Fortunately it takes considerable falling off to be easily observed in the print. The ordinary lens takes in an *angle of view* of 35° to 60° while some of the ordinary wide angle lenses will take in 80° and the extreme wide angle may cover 135°, Fig. 41. The narrow to medium angle lenses give pictures in which the perspective is most pleasing. In case one is forced to take the picture from a near point of view, a wide angle is necessary in order to get the whole subject on the plate. In extreme cases, such as photographing interiors, extreme wide angle lenses are necessary, but the perspective is exaggerated and is not pleasant.

105. **Depth of Focus.**—In nearly all picture work the object to be taken is not all at the same distance from the lens, and the picture is a projection of three-dimensional subjects onto the two-dimensional plate. For every distance of the object the lens has a distinct position of the focus, so that if the lens be focused for some part of the object the remainder, being at different distances, will not be in as good focus. How bad the focus will be in the rest of the picture will depend on several things, the actual differences in the distances of the parts considered, the focal length of the lens, and the size of the diaphragm. The first usually has to be taken

as it occurs but where there is any choice in the matter it will always improve the definition to have the objects as near together as possible. The actual amount of blurring which the eye will not detect will be fairly constant, that is, the image of a point

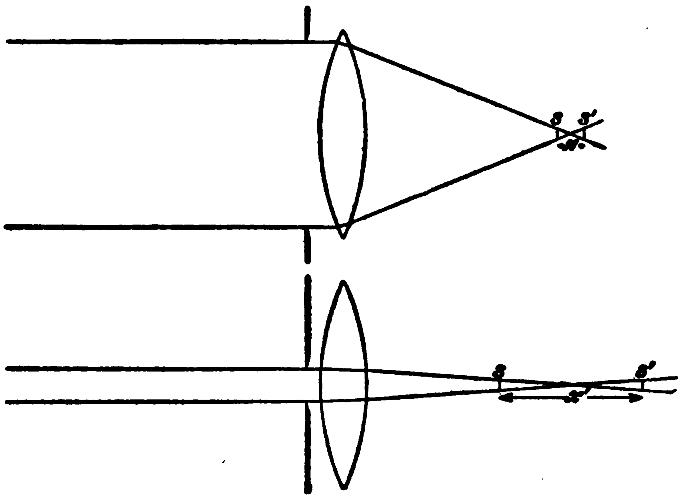


FIG. 42.

can be widened out into a circle of a definite size before we object to it as being blurred. It will be evident that with a short focus lens the difference in the object distances which will produce this allowable blurring will be much greater than with a longer focus lens. For this reason most of the fixed-focus cameras, where the lens is set for an object at a long distance away, use short focus

lenses and hence small plates, so that the whole field up to a few feet away will be in satisfactory focus. With lenses up to 3 or 3½ inch focal length this does fairly well as long as the object is 12 or 15 feet away, but when for the sake of portraits of visible size this distance is lessened, then the blurring becomes pronounced. The effect of the diaphragm also needs some consideration. The diagram, Fig. 42, shows that for a given amount of blurring the allowable difference in distance of the objects will be greater for a small diaphragm than for a larger one. This so-called "depth of focus" is much greater for the small diaphragm. When one goes to the very rapid lenses where the size of the diaphragm allowable is very great, up to ½ or 1/3 of the focal length, this blurring of objects even slightly out of the correct focal distance becomes very pronounced. It is painfully evident in pictures of rapidly moving objects (reflex camera work), where the diaphragm has to be very large to get sufficient light in the very short time which must be used so that the object may not move enough to show.

106. When one examines a lens maker's catalog he will see constant reference to the *speed* of the different lenses. Other things being equal, that is the speed of the plate, brightness of the day, size of the plate and focal length of lens, that lens which

will give the satisfactory definition with the larger stop will allow of the picture being taken in the least time, and is hence spoken of as the fastest lens. Lenses of different focal length may be com-

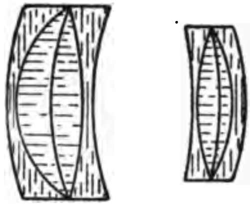


FIG. 43. Convertible Lens.

pared if the size of the diaphragm is measured in terms of the focal length, that is in the F numbers. So that the speed of the lens is usually spoken of in terms of the largest stop it will allow for satis-

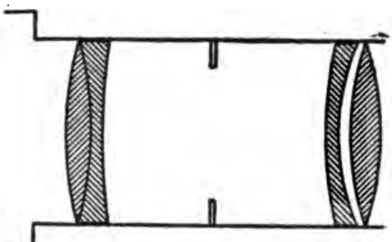


FIG. 44. Petzval's Portrait Lens.

factory definition and be referred to by the numbers of the "F" or "U. S." scale.

107. **Lens Types.**—The rapid rectilinear, Fig. 38, page 161, has already been mentioned as the important lens in the medium-priced cameras, and

of course there are all different grades of rapid rectilinear lenses, depending on the glass used for the different components and the care with which they are finished and mounted. The cheap cameras have single achromatic lenses, or in the cheapest kinds a single glass lens. Of these the deep meniscus type is the best, having the least spherical aberration.

Some of the expensive doublet lenses have the different components of different focal lengths and even of different diameter, Fig. 43. Each component is corrected as far as possible so that either one may be removed from the tube, thus providing the possibility of three different focal lengths for different work, and hence they are called *convertible* lenses.

The Petzval portrait lens, Fig. 44, has been such an important lens in the past that it deserves mention, but it is not as good for its own special work as some of the more modern lenses, while it is more expensive to make and so is being gradually displaced, but the professional photographers still use a good many of them. It is of the doublet type, but the spherical aberration is corrected by a meniscus component separated by an air space from the next member. By varying the air space, the spherical aberration can be varied at will for soft or for sharp definition.

Some good modern doublets are the Zeiss [4] "Tessar," Goerz [5] "Dagor," Cooke [6] Anastigmat, Voightländer [7] "Heliar," Harris [8] "Euryplan."

108. **Telephoto Lens.**—There is yet one lens which requires some mention. It is the telephoto combination. The purpose is to enlarge the size of the picture without the great extension of the bellows required when the enlarging is done

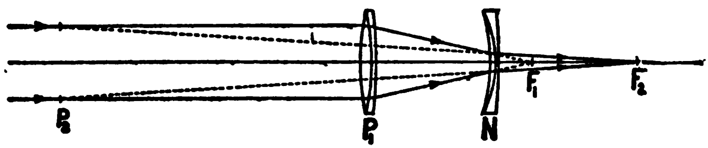


FIG. 45. Telephoto Lens.

by simply increasing the focal length of the lens, which moreover leads to clumsy apparatus and requires a very steady support. The idea of the telephoto lens will be best obtained from the diagram, Fig. 45. It consists of the usual high class lens of the converging type, and at some distance behind it is placed a diverging lens. As shown in the diagram this second lens reduces the convergency of the rays so that they will strike the plate as if they had come through a very long

[4] Bausch & Lomb Optical Co., Rochester, New York.
[5] C. P. Goerz American Optical Co., 317 E. 34th St., New York.
[6] Taylor, Taylor and Hobson, 1133 Broadway, New York.
[7] Voightländer & Son, A. G., 225 Fifth Avenue, New York.
[8] Ralph Harris & Co., 26 Bromfield St., Boston, Mass.

focus lens. By varying the distance between the two lenses the apparent focal length changes and with it the size of the picture. The greatest separation is when the diverging lens is at the focus of the converging, when the magnification becomes infinite, and in practice the separation is always less than this. In the first arrangements of this combination put out by the lens makers the highest possible magnification was sought, and this was not always needed and was frequently the cause of poor results. So that now the magnifications usually run from four to ten or twelve. The camera requires steady support and the exposures have to be much longer than with the usual lens. If the arrangements are good the picture is better in the way of detail than can be obtained by enlarging a picture taken with an ordinary lens.[9] The diverging lens part of the combination is not very expensive, and it is used with the high grade general purpose lens.

There are a number of very readable books on lenses, for example:

C. L. Johnson, *Photographic Optics and Color Photography.*

J. T. Taylor, *Optics of Photography and Photographic Lenses.*

[9] See "Telephotography," *Photominiature,* No. 26.

Beck, *Photographic Lenses.*

While a more advanced treatment may be found in:

Otto Lummer, *Photographic Optics,* translated by S. P. Thompson.

CHAPTER VIII

COLOR PHOTOGRAPHY

109. There are a great many reasonably workable methods of taking photographs of objects where the photograph will show the colors as well as the geometrical shape and the light and shade. This is a different problem from the photography of colored objects, where the purpose was to render the visual light and shade of the colors in one color, e.g., gray. Now we desire to include the color itself in the finished picture.

These processes may be grouped immediately into two classes: I. those in which no pigments are used to produce the colored picture, of which the Lippmann process is the only one, and II. those usually known as three-color processes which use pigment to give color to the print, which includes a great number of methods. This last class may be subdivided again:

1. Those using three negatives
   (A) Addition positives
   (B) Subtraction positives
2. Those using a mosaic three-colored screen
3. One using the bleaching by light of some dyes.

CLASS I. LIPPMANN PROCESS

110. To understand the Lippmann process it will be necessary to review something of the theory of light. The generally accepted theory is that light is a wave motion in an elastic medium, the wave motion being of the transverse type, the velocity being very great and the wave lengths very short, a few thousandths of a mm. If two wave motions

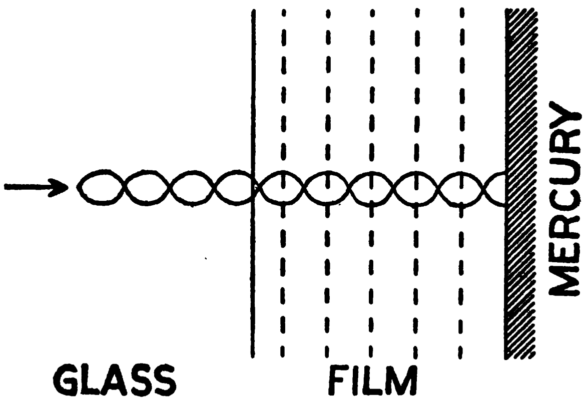


FIG. 46. Lipmann Process.

of the same wave length go in opposite directions in the same medium they will interfere in such a way as to set up standing waves, that is, places where the two waves destroy each other, and places where they help each other, Fig. 46. One train of waves may be most easily formed by the reflec-

tion of the first train, and there are many examples of standing waves by such an arrangement. Light being a wave motion should allow of the formation of standing waves. That is to say, if a beam of light be allowed to fall perpendicularly on a mirror, the two beams passing in opposite directions on the same path should set up standing waves, that is to say, places of no light and places of increased light following each other regularly along this path. Suppose now that the path of the light immediately above the mirror be filled with a semi-transparent sensitive film, then the standing waves should be formed in it, and the places-of-no-wave should not be acted on by any light, and the intermediate places should be strongly acted on. If this film be developed it should show a series of layers of deposit of silver where the light acted, with intermediate places where the silver will not be reduced. The unaffected silver haloid can be dissolved out by hypo leaving this series of layers of reduced silver. If a thin strip is cut off the edge of any piece of the film and then examined under the microscope, it will be seen to be filled with a series of opaque layers separated by transparent portions, Fig. 47, page 160, the layers running parallel to the surface of the film, and the number of such layers may run up into the hundreds.[1]

[1] Ives, *Astrophysical Journal*, 27, 325 (1908).

Let us follow the argument a little farther. If one holds this layer film up in front of one's face with the light coming past the head so as to fall on the many layered film perpendicularly, each is nearly transparent but will reflect some light so that the light which is reflected to the eye will be the sum of the reflections from these different layers.

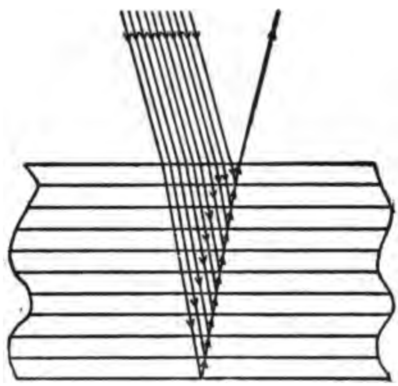


FIG. 48. Diagram showing how the light reflected from the different layers in the Lippmann film, returns along one line and therefore interferes destructively unless the wave length of the light is twice the distance between the layers.

The light reflected from two layers will add together to produce more light only if the two waves are in phase, and this will only be the case when the distance between the layers is half a wave length of the light used. In consequence the colors which are not of the right length of wave to agree with the distance between the layers will be destroyed

by interference, while the light which agrees with this length will be increased by each successive addition of more light by lower layers, Fig. 48. The space between the layers was determined by the light which fell upon the film, and therefore the film will look this same color when viewed perpendicularly afterward.

Lippmann argued very much like this above, and it was looked on as a great triumph of the wave theory that it worked almost exactly as expected. There are a number of experimental details and difficulties that the theory does not take any account of. The film has to be very thin so that it will not be practically opaque to the light falling upon it, so that the ordinary plates will not serve but ones with specially thin films have to be made. The reflector must be in intimate contact with the film, which is usually accomplished by exposing from the glass side and making the film the side of a box containing mercury. The film is very thin and develops very rapidly, and must not be developed very long or it will be much too dense. If it is treated with hypo the loss of silver from the undeveloped layers will bring the layers of reduced silver a little closer together, and the colors will be shifted a little.

The exposure is made in the camera with the mercury against the sensitive film, and the expo-

sures have to be long on account of the fine grained (and therefore slow) emulsion which has to be used. It is a difficult process for a patient, skillful worker. Pictures of such a subject as the spectrum, where the colors are formed of one wave length, are reproduced so that one has no difficulty in believing that the spectrum is actually seen. But when one asks the film to reproduce the ordinary colors of colored objects where the colors are mixtures of a lot of wave lengths the rendering is not nearly so good, but still the pictures are well worth while. White, being a mixture of all the colors, is the most difficult to render and is the stumbling block in most cases. The method is of immense scientific interest but is too difficult for ordinary use.[2]

Class II. Three-Color Processes

111. All of the processes for the making of pictures in colors by the use of pigments in a mechanical way are based on observations first made by Maxwell. The result of these observations can be summarized in the statement that any color as perceived by the eye may be imitated by mixing

[2] In the *British Journal Color Supplement* for November 4, 1910, will be found detailed directions for the Zeiss apparatus and Jahr plates for working this process.

in proportions suitable for the particular case three primary colors, orange-red, green, and blue-violet. There is some latitude in the choice of these three colors, but if the visible spectrum be divided into three about equal parts each will be about the color required. To make use of this imitation of the original colors, it is necessary to make three pictures in the three primary colors and superpose them. The methods for doing this differ in cases (1), (2), and (3), page 173.

112. **Case I.**—In both modifications of the three-negative process, three pictures are taken on color-sensitive plates, each through a screen colored with one of the three primary colors. That is, the negative taken through the red screen will have a deposit of silver wherever the original subject reflected red light. This will mean not only the red objects, but all objects of mixed colors which include some red in the mixture, and all objects reflecting white light which most objects do to some extent. So also for the other negatives, that is each one will contain a lot of detail, and unless there are some markedly colored objects there will be trouble in distinguishing the three negatives. These negatives are called the "color records," and there are a variety of methods for translating the records again into color.

113. (a) **The additive method.** This is the most

direct and simplest in principle of the methods. Three positives are made from the three negatives and each provided with a screen colored like the screen through which the negative was taken. These three positives are then placed in three different projecting lanterns, each positive with the original taking screen and the three pictures matched carefully on the screen. This will reproduce the original beautifully, but requires an expensive outfit and takes time to change from one picture to another. A simpler and cheaper arrangement is Ives Kromskop,[3] in which an arrangement of transparent glass mirrors allows of seeing the three-colored pictures superposed, thus giving the mixed colors of the original, see Fig. 49. The apparatus may also be arranged for projection with one lantern.

114. **(b) The subtractive method.** This is less simple in principle but more usable practically. In this group are a number of distinct processes all requiring the same three-color negatives. Of these the important ones are (a) Carbon (including Sanger-Shepherd,[4] Autotype, Rotary, Tripack,[5]), (b)

[3] For an excellent working description see König-Wall *Natural Color Photography.*

[4] Supplies may be obtained from Sanger-Shepherd & Co., Ltd., 5 Gray's Inn Passage, Red Lion St., Holborn, London W. C., England.

[5] Supplies and directions may be obtained from Hess-Ives' Corporation, 1201 Race St., Philadelphia, Pa.

Pinatype, (c) Traube Iodide, (d) Printing press. Three-colored prints are made one from each of the three negatives and superposed. The printing col-

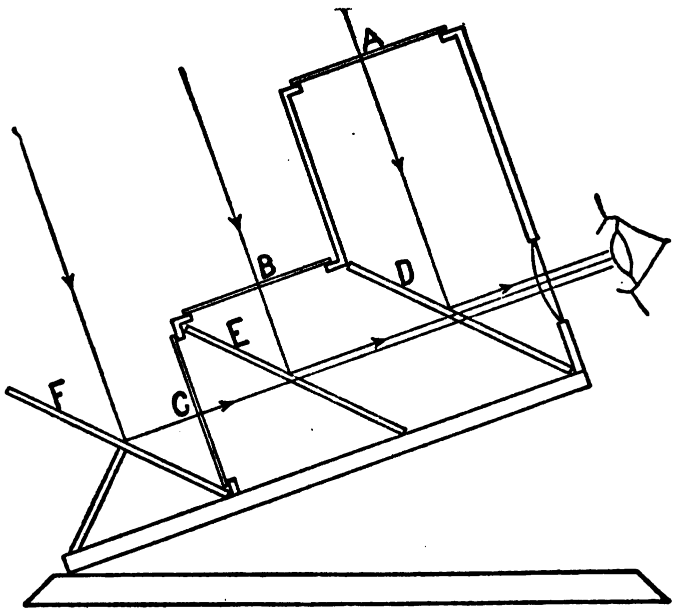


Fig. 49. Ives Kromskop.

ors used require some explanation. If one printed, for example, the red sensation negative on red material, then since every red object leaves a deposit on the negative, all the red objects will be white in the red print and all the rest of the picture which included no red will have red all over it.

Similarly for the other three colors. So that this evidently will not do; as a matter of fact every object would appear in its complementary color. But if the negatives be printed each in the complementary color to its taking screen, then the picture will come out right. Let us represent the spectrum by a straight line thus, *r o y g b v;* then the printing colors and screens will be as follows, the horizontal lines meaning that these colors of light are present.

	Screen			Printing color			
	r o	y g	b v	r o	y g	b v	
RED	—				—	—	GREEN-BLUE
GREEN		—		—		—	RED (purplish)
BLUE-VIOLET			—	—	—		YELLOW

Now consider a red object in the picture. In the red sensation negative there will be a deposit at this place, and therefore this object will be represented by a clear place in the print. In both the other prints there will be clear places in the negatives and therefore deposit in the print. The only color not absorbed by either of these two deposits is the red, either one or the other deposit absorbing the rest of the spectrum. That is, in the print this place is

red. So also for the other colored objects and for the mixed colored objects.

115. (a) Just a few words as to how the different colored prints are made in the different methods. The *carbon process* of printing has already been described, Art. 90. A number of manufacturers[6] are making tissue in the three colors required for these prints. From the previous description it will be easily seen how readily the three prints can be superposed. To avoid the double transfer one firm makes the tissue on a transparent celluloid support, and the printing is done through the support. In this case the insoluble part of the gelatine will be next the support, and the soluble part may be washed off without any preliminary transfer. To superpose the three pictures exactly is not an easy operation, and it requires a good deal of care to keep the three pictures of the same size.

116. (b) The *Pinatype process*[7] depends on the different actions of soluble and insoluble gelatine when treated with certain dyes. When a film of soluble gelatine is dipped in a solution of one of these dyes the dye is absorbed by the gelatine and

[6] Autotype supplies for all kinds of carbon printing may be obtained from George Murphy, 57 E. 9th St., New York.

[7] Supplies, with detailed directions, may be obtained from Meister, Lucius & Brüning, Hoechst am Main, Germany, or from the American agents, Farbwerke-Hoechst, P. O. Box 753, New York.

stains it deeply. The insoluble gelatine will not absorb the dye. A film of clear, soft gelatine is sensitized with chromate and then exposed under a positive made from, say, the original red sensation negative. The gelatine film is washed free of chromate and then soaked in the dye solution (green-blue). The dye will be absorbed by the soluble gelatine, and not by the insoluble, and the detail of the picture shows clearly. The other two colors are printed in the same way; the three are superposed and looked through, and will show the colors of the original object if the depth of color of each of the three prints is right. This, of course, requires thin, transparent supports for each print. By a simple extension the prints may be duplicated many times and on a paper support. One of the above dyed prints is dyed very deeply and then rubbed into close contact with a wet, soluble-gelatine surface. The dye transfers itself slowly to the new gelatine, which after a few minutes will show the picture clearly. Each of the other colors is transferred in the same way to the same gelatine film, which will then show the picture in the original colors. The difficult points are to get all three pictures correctly superposed and printed to the right depth of color. As might be expected from the process the prints are not very sharp but are not unpleasantly fuzzy and may be duplicated almost indefinitely.

117. (c) All of you will recall that dry plates are made sensitive to the spectrum by dipping the dry plates in a solution of a dye. The particles of silver bromide absorb a small quantity of the dye. Silver iodide will absorb large quantities of many dyes but, unlike silver bromide, the dye has but little effect on the color sensitiveness. Traube has made this property of silver iodide the foundation of a process for printing in one or more colors.[8] The silver in an ordinary positive on paper or other support is changed over to silver iodide by immersing in a solution of potassium ferricyanide and potassium iodide (compare the ferricyanide reducer). This bleached positive is then immersed in a solution of the dye which stains both iodide and gelatine but washes readily out of the gelatine. The next step is to dissolve out the silver iodide by a solution of hypo, which also has to contain a substance to render the dye insoluble, a mordant, such as tannic acid. The silver image is thus replaced by a dye image whose color and density may be regulated almost at will by the choice of dye and density of the original silver positive. The modification necessary to make three-color prints is slight. The required three-color prints on transparent supports are made from the red, green, and blue sensation

[8] Supplies and detailed directions may be obtained from Otto Perutz, München, Dachauerstrasse 50, Germany.

negatives and superposed. The process offers advantages to the amateur in its similarity to the customary process and its ease of control.

118. (d) The printing press using colored printing inks occupies first rank when measured by the number of pictures produced. In the usual three-color process, the three negatives described above are used to make three printing blocks, and each of these is used to impress its appropriate color on the print. In skillful hands the results are exceedingly fine. For the making of one copy it would be a very expensive process, but when the cost of the blocks is charged against some thousands of copies, the cost per copy is not large. It is a difficult process requiring extensive equipment and highly skilled workers, so that it is not at all suitable for general use.

119. Case 2.—Mosaic Screen Process.[9]—At the present time these are the most popular with the ordinary worker. The method was first worked out by Professor Joly of Dublin. A number of makes have been tried commercially—Joly, MacDonough, Warner-Powrie, Thames, Krayn, Omnicolor, Autochrome, Dufay, Leto, Paget,[10] the last

[9] Mees, C. E. K., "History of Color Screen Photography," *British Jour. Sup.*, 1908, p. 12. Mees & Pledge, "A General Discussion," *British Jour. Sup.* to vol. 57, 45 (1910).

[10] Supplies and directions can be obtained from Herbert & Huesgen Co., 456 Fourth Avenue, New York.

four of which are still on the market. The theory is the same for all, and the general process of using the plates is also very similar. The Autochrome was the first commercial success and is still probably the best though some of the others are better in some particulars. The theory will be most readily understood from a detailed description of one plate, the Autochrome, and the others can be then related to it.

120. **Autochrome.**[11]—The process of making a plate is about as follows: a quantity of wheat starch is sifted to separate all but one size, about 0.015 mm. diameter. The sifted starch is divided into three portions, and each portion is dyed one of the three primary colors. The three portions are mixed very thoroughly, and if the dyeing has been satisfactory the mixture will be gray, almost black. A glass plate is coated with a sticky varnish, the starch grains dusted onto it, and then shaken off, so coating the plate with one layer of the colored grains. The interstices are filled with an opaque material, probably by dusting a much finer powder on, and all rolled flat and varnished with a waterproof varnish. On holding the plate up to the light it appears gray. If it did not it would

[11] If supplies cannot be obtained from a local dealer, they may be obtained from Lumière Jougla Co., 75 Fifth Ave., New York.

impose its color on the color of the finished picture. The grains are so small that the eye can not distinguish the individuals, and the resulting effect on a point of the retina is the sum of the effects of a group of the grains. If one could cover up part of the grains, then the color the spot would appear, would be that due to the uncovered grains. The three colors used for the grains are the three primary colors, red, green, and blue violet, by a suitable mixture of which any color may be imitated to the eye. So that by covering up a selected set of these colored grains the rest will imitate any color desired. The problem is to cover up the required set.

The next and final step in the preparation of the plate is to coat the waterproof varnish with a very thin layer of panchromatic emulsion. These plates are packed in boxes and shipped like ordinary dry plates.

To make the picture the plate is exposed in the camera like an ordinary plate except that the glass side of the plate is put toward the lens and allowance must be made for this in focusing, either by reversing the ground glass, or by moving the lens toward the plate a distance equal to the thickness of the plate after focusing on the ground glass. Since no emulsion can be made equally sensitive to all the colors, it is necessary to use a color screen

to lessen the effect of the blue and violet light. Both the mosaic screen and the color screen absorb considerable light so that the exposures have to be about 60 times that for a medium rapid dry plate. Also since the emulsion is so thin the latitude of exposure is very narrow, and exposures have to be very nearly correct to be at all satisfactory.

The exposed plate is developed, using a definite time or following the progress with a green light of a particular shade for which the emulsion is not very sensitive. The plate is washed and immersed in a solution which will dissolve the finely divided silver forming the negative image, so that there will be clear places in the negative everywhere where there was negative deposit, and negative deposit occurs only where red light struck the red grain, green light the green grain, and violet light the violet grain. So that when the deposit is removed these grains transmit light like that which came up to them in the camera. It is only necessary now to reduce the rest of the silver bromide to metallic silver by an ordinary developer, in order to block out effectively the grains which did not transmit light in the camera, after which the picture stands out clearly. Treatment with hypo may be omitted when all of the undeveloped silver bromide has been reduced by the second development. After the film is dry a coating with varnish makes

the picture more brilliant and less easily damaged. To protect it effectively it should also be covered with a piece of clear glass.

121. **Mosaic Screen Making.**—It will be evident from the above that the central point of the method is the use of the mosaic screen, and the different makes of plates mentioned above differ mainly in the character, and method of manufacture, of this screen. The first such screen was made by Joly, who ruled parallel lines in the three colors in order to cover the plate, so that the color elements were not dots but extended right across the plate. The MacDonough screen was made in very much the same way, but was too expensive to make, and it was difficult to get the colored strips in contact and yet not overlapping.

Another promising method (Krayn) was to make a pile of thin sheets of celluloid of the three colors, cement them together, and then take thin shavings off the edge of the sheets. This would give the color elements as lines, but they could be made into squares by cementing a pile of these shavings together so as to mix the lines and shaving again across the lines. But experiment showed unexpected difficulty in making thin enough celluloid sheets and also in making the shavings thin enough. The elements must be 150-200 to the inch to be at

all satisfactory, while the specimen the writer has seen had about 60.

Many of the other screens depend on the dyeing of a gelatine layer, for example, Warner-Powrie, Krayn, Dufay, etc. In making the Warner-Powrie screen a layer of gelatine or fish-glue is sensitized with chromate and then exposed under a screen composed of alternate opaque and transparent bands, the former being twice the width of the latter. The soluble part of the gelatine is then washed away and the rest, consisting of the insoluble bands immersed in a green dye which is afterwards made fast or mordanted by immersion in tannic acid solution. This will give a plate covered with green lines. Another layer of gelatine is then spread over these green lines and the whole process repeated but setting the screen so that the new set of lines (dyed red) fall between but next to the blue lines. The plate is coated a third time and exposed through the other lines to blue light, which is, therefore, absorbed by the green and red lines, so that the gelatine is hardened only in the as yet uncolored areas. The plate is then washed, dyed blue, and mordanted. the process seems to be a good one.

Another method for coloring the film in patches is used in the Dufay [12] screen. A soft gelatine film

[12] Made by R. Guilleminot Boespflug & Cie., 22 Rue de Chateaudun, Paris, agent in U. S. being George Murphy, 57 E. Ninth Street, New York.

is printed in a printing press with parallel lines of a greasy ink. This plate is then immersed in a water solution of a dye. The solution will not pass into the gelatine through the greasy ink but only in the clear places between. The plate can now be varnished with a waterproof varnish. When dry the application of a solvent for the greasy ink and a little friction will clear off the greasy ink and its varnish covering, leaving the clear parts of the film exposed, but the dyed strips protected by the varnish. The process is then repeated but with the lines running across the previous ones. This will give two colors, the first lines and the second squares and the final square left exposed by the two previous processes is dyed the third color. The Dufay screen is an excellent one mechanically, having sharply marked edges to the color dots and being reasonably fine.

The latest plate on the market is the Paget Prize Plate,[18] in which the mosaic screen and sensitive plate are separate. They are placed in contact for exposing but are separated for developing and making a contact transparency, which is bound up with a different mosaic screen. This allows of duplication, but the screen has to be somewhat coarse, and there is the serious difficulty of securing good reg-

[18] May be obtained from Herbert & Huesgen Co., 456 Fourth Ave., New York.

istration all over the plate between the color elements and the positive.

A great many other methods have been patented for making these mosaic screens. A good method offers large financial returns.

122. The use of these mosaic screen plates puts in the hands of the careful amateur a means of taking pictures in their natural colors with only one exposure and with comparatively little manipulation. The pictures are satisfactory in many ways. But they have certain disadvantages. They are all transparencies, and copies are not very satisfactory, being particularly unsatisfactory with the Autochromes. So that each picture requires a new exposure. The most satisfactory method of reproduction at present is by means of the three negative-printing press method, where the mosaic screen picture is treated as a colored subject to be copied. A method usable by the ordinary worker is in great demand. The following method offers a good deal of promise.

Class 3. Bleach-out Process

123. This is based on the fact long known that many dyes which bleach readily in the light are bleached by the colors of light which they absorb, and which is the complementary color to which they appear. For example, if a red and blue dye of this

type be mixed and coated on paper, and say, blue light be allowed to fall on it, the red dye will absorb the blue light and be bleached, while the blue dye will reflect the blue light and remain unbleached. The paper will hence turn blue. It will, therefore, only be necessary to mix three such fugitive dyes, of the three primary colors—red, green, and blue-violet—coat them on paper and expose the paper under a mosaic screen picture. Where red light gets through it will bleach the other two dyes, leaving the spot red; and similarly for the other colors. The mosaic screen picture will be reproduced in colors. But the process is not perfected yet—one difficulty being to make the colors stop bleaching when the printing is done, that is to "fix" the picture. This is partly attained by using dyes which bleach much more rapidly in the presence of certain reagents like anethol for example, which may be washed out. The other serious difficulty is that the different colors of light bleach the dyes at very different rates—so that for instance when the red is bleached the blue will not be. Two or three different makes of such papers have been put on the market but they do not seem to be very successful yet.

CHAPTER IX

GOOD PICTURES

124. A picture is a representation of a three-dimensional subject on a two-dimensional plane. It is a representation, not the thing itself, and as such is necessarily a counterfeit or an imitation. Truth or untruth in a picture has therefore a very special meaning, in fact truth is determined by how far the picture fills the purpose of the worker. A photographic surveyor desires pictures which shall be accurate geometric projections of the subject showing every detail near and far. For him the truth is determined by how far his pictures fill these requirements. On the other hand a portrait of a familiar person has to represent for us a variety of changing attitudes and expressions, and a detailed accurate delineation of one momentary condition may satisfy this desire to some extent, but the probabilities are very much against it serving as well as a picture in which the rendering is less complete because the delineation is then not so sharply one mood and because we do not remember the fine detail as a rule so well as the general effect. There

is hardly a professional portrait made which is not retouched. That is a portrait is to be judged on the basis of suggestion of the person pictured.

125. In a general way pictures may be divided into two classes:

(a) **Record Pictures,** where the aim is a geometric rendering of the subject. Pictures of this class are of the very greatest importance, particularly in all scientific work. The purpose makes this class include the great majority of amateur photographs taken as records of persons and places, and also the great majority of portraits. There is no doubt that this purpose is the predominant one in the vast majority of pictures, and the world could much better afford to lose the second class than this one.

(b) **Pictorial Pictures,** where the essential purpose is to attract, arouse, and generally please the beholder, not so much by the particular scene pictured as by ideas suggested. As such they appeal to the imagination, and to attain their purpose it is not at all necessary that the object forming the actual subject should be suggested by the finished picture. In this class are to be placed many paintings and a small proportion of photographs. Any liberties with the geometry, with the lighting, with the color, are justified by aiding toward the object sought. It must be noted however that such liberties must be handled in a masterly way or they

have an effect very different from that intended.

While these two purposes should be clearly distinguished and acknowledged in their extreme examples, there are relatively few pictures which come only in one class. The first ideal of the young photographer, as also of the early school of photography, is the record photograph, and so well understood is this ideal and so useful that only a few unbalanced "Art" workers try to belittle it. But the worker soon observes that while equally good records, some of his photographs are more pleasing, are turned to oftener, and are exhibited to his friends. He begins to work for these effects as well as for the original record purpose, and he hence begins to include the ideas of the second class. The great majority of workers never give up precedence of their first purpose, and a study of the mass of pictures of those who have makes it seem well it should be so. Very few of us have the temperament or time to be artists, but we can often recognize and appreciate good imaginative work; while botched work of this kind is an even more serious offense to the ordinary man than to the artist who sympathizes more readily with its aim and who understands its difficulty. This chapter is written for the ordinary worker who is progressing sufficiently with the straight record work that he desires to include as far as possible more

of the somewhat intangible features which make some pictures more pleasing than others.

126. **Picture Composition.**—The choice and arrangement of the detail forming a picture has received the general name of composition. The subject is a very extensive one, but it lacks the definiteness and precision characteristic of the sciences. Several centuries of vigorous controversy by both painter and critic has not led to any great unanimity, and any generalizations are opposed by marked exceptions. Most writers admit that there are a group of rules followed in general by all great painters, though at times they may break any of them. From the discussion it also appears that one great purpose served by such controversies has been the attention to such detail thereby promoted.

The literature [1] upon the general subject is voluminous and varied, but the great majority of such books are by painters for the use of painters. On account of the great difference in method between painting and photography, combined with the restrictions inherent in photographic composition and the loss of all color, these books are not very serviceable to the young photographer. There are, however, an increasing number of books [2] and maga-

[1] Joshua Reynolds, *Discourses;* Burnett, *Art Essays.*

[2] R. H. Poore, *Pictorial Composition;* Sadakichi Hartmann, *Landscape and Figure Composition;* H. P. Robinson, *Pictorial Effect in Photography.*

zine [8] articles written especially for photographers which well repay study.

The control by the photographer over his subject as compared, for instance, with that by the painter is very limited, being restricted to choice of subject as a whole, of point of view, and of lighting. The treatment following exposure may also modify the picture materially but, only by suppression, seldom satisfactorily by addition. In the following articles an attempt is made to review systematically only the most elementary aspect of photographic composition, treating it in the way it is apt to present itself to the young photographer and hoping thereby to awaken an interest in the subject that will lead to further study elsewhere.

127. **Unity.**—Every picture needs some definite fairly conspicuous object to form the center of interest and to which all the rest of the picture will be subordinate. It is the reason for the existence of the picture. There is little limitation to what may be so used except that it must have enough human interest to justify the important position. A human figure or face is preëminently such an object, and its treatment, portraiture, is an important branch of picture making. In landscape pictures an

[8] R. H. Poore, "Figure Composition," *Photominiature,* No. 64; F. C. Lambert, "Pictorial Principles," *Photominiature,* No. 53; F. Weston, "Composition," *American Photo.,* p. 325 (1914).

interesting glimpse of a building, or a lake, or a pretty shore line, or a group of cattle, may readily serve as the basis of a picture and justify its existence.

The best position in the picture for the center of interest varies, but no one advises that it be placed at the geometric center. Somewhere near but not at the center is the favorite place. When placed very far from the center it requires very special arrangements to be pleasing.

128. **Simplicity.**—To be satisfactory a picture must not include too much lest it divide and thereby weaken the interest. The commonest mistake with the camera is to seek for a point of view which will show as much as possible. While this serves a record purpose it weakens decidedly the appeal as a picture. A compromise between the two purposes is often on the whole a gain. If unnecessary or distracting detail cannot be omitted by choice of point of view, it can often be eliminated later or at least be rendered less conspicuous by loss of its fine detail or by subdued lighting. To be effective all the subordinate detail should be naturally associated with the main subject and should be so placed if possible as to direct attention to it. For the landscape photographer the amount of such choice is decidedly limited, but in portrait work the background is normally entirely controllable; directly around the head

it is preferably of different brightness from the head outline so as to show this where desired and to give relief, while away from the head, detail should merely soften the blank area but not be sufficient to distract attention from the face.

129. In landscape work the *foreground* offers special difficulties. On account of the nearness to the camera, the area occupied on the picture is relatively large, and thereby small, unimportant detail becomes unfortunately conspicuous. Slight sideways shift of the camera will move a conspicuous bit of detail to the corner or partly off the plate, in which position it may possibly help the composition, or it may be moved off the plate altogether. Also the foreground may occupy too large a fraction of the area of the print. The first correction usually tried is to raise the lens, but if feasible it is usually much better to raise the camera itself. Failing these, it becomes necessary to trim the print.

130. The position in the picture occupied by the *sky-line* is important. Also often when it is absent there will be some other line which will take its place. Our habit of looking horizontally places the horizon somewhere in the middle of the view, and consequently the observer recognizes the view point most readily when the sky-line is somewhere near the center of the picture. If it deviates widely from that the observer has to recognize a somewhat unusual

view point—which of course for special reasons may be a distinct gain in case the rest of the picture enforces it, but only in such cases is it an advantage.

131. A print where the *sky* is pure white paper is at a great disadvantage when compared with one showing clouds. Cloud-forms in themselves are often very beautiful, and they have such significance for us in our daily life, that a picture using them to fill in an otherwise empty area gains greatly. There are several ways in which cloud-forms may be obtained in the print. They may be put in, using a wad of cotton, or a brush, or a pencil, but it takes great skill to make them look natural in shading and form. Or with a little care they may be printed in from one negative and the rest of the picture from another. Outside of the difficulty of matching them on the sky-line, is the greater difficulty of making the cloud shapes fit the horizon, and the shadows they cast agree with those in the landscape. Without being always able to specify, one often feels that there is something incongruous. By all means the best procedure is to take both clouds and landscape on the same plate at the same time, by using a suitable color sensitive plate and a color screen. The temptation to make the clouds too prominent is strong, and one should never forget that both clouds and sky are very much brighter than the earth. This usually requires a rather transparent color

screen, factor of two or four, or possibly eight, and the whole proceeding requires patient watching for a day when clouds and light are suitable.

132. **Aerial Perspective.**—The geometric perspective will be considered later, but in landscape work there is an effect due to the varying density of the air—a great exaggeration of which one gets by looking at something across a hot stove—leading to slight movements of the image and therefore blurring, whose amount depends on the distance. There is sometimes an actually visible tremor which like all motion can only be imperfectly suggested in a picture. Added to this is the effect of dust always present in the air but in greatly varying quantity. Its effect is to scatter the light coming from a distant object, thereby reducing its brilliancy but at the same time to add to its brilliancy by light scattered from other images. The result is a tendency to bring all distant objects toward the same brightness by dulling the bright ones and brightening the dark ones. Also since the added light is a bluish white, the result is to dull all bright colors by an admixture of white light. Unfortunately for the photographer the amount of the scattering by the atmospheric dust depends on the color of the light being markedly greater for the blue end of the spectrum. For not very luminous objects the loss of blue is more than made up by the added light which has been

scattered from other images, the result being the overlaying of all distant images with a marked blue haze, conversely a reddening of all relatively bright objects, as in sunset and sunrise. The photograph with the ordinary emulsion is practically taken with the blue and violet light, so that this blue haze, besides leveling light contrast, produces so much deposit in the negative as to obscure in the print distant detail ordinarily visible. Hence practically distant objects require less exposure than near ones. The whole objectionable effect in the plate can be corrected by using a plate whose sensitiveness curve is approximately that of the visibility curve for the eye, see Art. 51. Or the same result may be obtained by using a color sensitive plate and a matched color screen whose combined effect is to match the visibility curve of the eye. With suitable screens the effect on the eye can be imitated as exactly as desired or the rendering of distant detail can be accentuated or obscured. Except for special reasons it is best to imitate the amount of detail the eye sees. This will usually mean using a good panchromatic plate and an adjusted screen and giving a time exposure with a relatively small stop. The time exposure also allows the atmospheric tremor to produce its visible amount of blurring.

133. **Color in Subject.**—The necessity of trans-

lating the color of the ordinary subject into monotone leads to two separate difficulties, one purely photographic, the other pictorial. The first, that of making the dry plate translate the color according to its visual brightness, has been discussed previously in some detail, Art. 51. It is only necessary to add here a few words on the importance of doing it correctly by the use of good color sensitive plates and matched screens. The more pronounced the color the more obvious the improvement; the browns and particularly the greens in landscape, and freckles, skin-tone, and blue eye in portraiture, are very untrue with the ordinary plate, and repay generously in truthful rendering and personal satisfaction any added difficulty in the use of special plates and screens. In fact one can hardly urge too strongly their uniform use for all subjects showing definite color, distance, or clouds.

The second difficulty referred to above, the pictorial one, is that one must estimate the effect of the picture, minus color, from the beautifully colored image on the ground glass. Until hardened by repetition one is always disappointed by the print, and one of the major factors in producing this feeling is the loss of color. Practically one can get some assistance by using a screen, yellow for example, transmitting a moderately narrow band of the spectrum. This will remove the color from the image

but will not give the correct brightness to the colored objects. One has to be wary of brilliantly colored subjects, such as flower beds, whose color may be their predominant attraction. The effort necessary to observe form, light and shade, and to neglect color, leads directly to greater command over the factors themselves.

134. **Lighting.**—Next in importance to subject and point of view is the lighting. It should also be made to serve the purpose of the picture in exhibiting the center of interest. The position of the sun, that is the time of day, by the spots lighted and the shadows cast, has an immense effect on the resulting picture. No one can advise what lighting is best; it has to be examined and tried in each case by the worker. One can say however that as a rule harsh lighting, that is direct sunlight, with its deep shadows, is not as desirable as a softer more uniform lighting, where the shadows, being somewhat lighted, show some detail. Of course there are times when glaring sunlight exhibits the aspect one wishes to show—a camel on the Sahara desert for example—but these subjects are exceptional. A partly cloudy or even a heavily cloudy day is in general to be preferred, provided of course there is not motion enough to interfere with the required time of exposure. On the other hand the lighting can be too uniform, so that the shadows are hardly noticeable,

and one of the important features by which we recognize shape and perspective will be lost. This is particularly noticeable in portraiture, where the desired roundness and relief—representation of three dimensions—is sought after regularly by a stronger lighting to one side and over the head. The other side and below must not be neglected entirely but be lighted sufficiently to show some detail. Considerable variety is obtainable by varying the relative strengths of these lightings, thereby varying the amount of detail in the shadows and the amount of suggestion of the third dimension.

135. **Notan** (Chiaroscuro, or mass effect).—There is another aspect of composition to be considered which is of great importance in painting and engraving, so much so that whole schools have been founded on it. This is the view which looks upon the whole picture as groupings of masses of light and dark. The detail in each mass is temporarily neglected or blurred over, and the resultant group of areas studied as to whether they form a beautiful pattern. This pattern forms a more or less satisfactory basis for many pictures, so that the artist may neglect entirely to fill in detail, or only a meager amount, thus making this pattern the whole picture. One does not need to go this far to make use of the idea, and every composition should be considered as

to whether the grouping of the large masses is pleasing.[4]

136. **Balance.**—The most important consideration as to whether this pattern will be pleasing or not is what is called balance. In a general way this means that if the picture be divided vertically (most important) or horizontally, approximately in half, the interesting features will be disposed about equally as regards general interest or attractiveness on each side of the dividing line. Also it is to be noted that an interesting detail gains in its effect on the balance as it is moved away from the center, and that objects showing little detail do not hold the attention for long, so that their importance in the balance can therefore be adjusted by changing the sharpness of focusing. When one first looks at a picture the impulse is to run the eye swiftly over the whole area, and the first impression is then strongly influenced by the balance. After the first quick survey one settles down to examine the interesting detail. The importance of unity and balance in the final judgment is very great.

137. **Focal Length of Lens.**—There are some points about the camera which by their effect on the satisfaction from the picture need some further consideration. If the picture is to be a representation

[4] See Poore, *Pictorial Composition*, for an excellent discussion of the various possible groupings.

of a natural scene it should resemble the view through a window frame with the observer using only one eye. If the eye is kept in one position—for example by observing through a hole in a fixed screen—then the scene could be copied with a pencil faithfully on the glass. On account of the actual construction of the human eye the glass to be distinguished at all must be five or six inches from the eye, and to be seen with the greatest comfort and clearness it has to be ten or twelve inches. Anyone observing a small picture instinctively adjusts it to this distance of distinct vision. If the focal length of the lens used in making the picture is so short that to get the view through the window effect the observer has to put the print four or five inches from his eye, then when put at ten or twelve inches it will not look natural. The perspective will not look right, the foreground will be exaggerated in comparison with the distance, and parallel lines will not converge as they do in the window drawing. This becomes very marked in some of the beautifully compact, convenient vest pocket cameras, where the focal length of the lens runs around one and a half inches. On this basis alone the ideal focal length would be ten to twelve inches, but the variation allowable before the ordinary eye observes it is large, so that lenses of five inches focal length are moderately satisfactory. Difficulty on account of too great

focal length is rarely met with, as such focal lengths are too large for convenient use, Fig. 28, p. 146.

138. **Distortion from Short Focal Length.**— The actual size of the image on the plane of the picture is approximately inversely proportional to the object distance from the lens. That is, the tip of the nose being nearer to the lens than the eyes will be drawn to a greater scale. So also if the hands are held in front they will be proportionately too large. This is inevitably the case even in the window frame drawing described above. The difficulty is that a picture in which the perspective including distortion, would be correct if viewed at, say, five inches, is actually viewed at ten inches, so that neither perspective nor distortion match with one's experience, that is with the window drawing. If, however, the subject is kept at a greater distance by the use of a longer focus lens, the perspective and distortion become more nearly that with which we are familiar, that is it approaches more nearly to the window frame drawing, see Fig. 28, page 146. This effect is particularly troublesome where in portraits and in pictures of small objects, the camera is moved close up so that the area occupied by the image will be large enough to show the desired detail. The only solution is a longer focus lens.

139. **Angle of View.**—Using both eyes, one can readily distinguish moving objects where the angle

of view between them is 180°, which is greater than any photographic lens. But the detail which the eyes can observe when so used is very small and the effort required way beyond the ordinary use. The user of spectacles is hardly troubled by the limitation of his angle of view. It seems that the angle of view of the eyes used freely and without direct effort is hardly 60°. In the camera an angle of 60 to 70° is to be preferred, and one can make a practice of trimming the print freely. Angles of view of more than 70° become progressively more unpleasant because they demand an unusual effort on the part of the observer to interpret the picture.

140. **Focusing.**—On account of the narrow depth of focus of all lenses used with the ordinary apertures, it becomes necessary to select a plane in the three-dimensional subject where the focusing shall be sharpest. On each side of this plane the definition will fall off, the most rapidly with the largest apertures. Ordinarily the center of interest in the picture is the place to focus most sharply, and where light and motion conditions permit, the choice of aperture, and therefore the depth of focus can be profitably considered in relation to how strongly one wishes to concentrate attention on the center of interest by causing the neighboring objects to go rapidly out of focus. For example the practice in portraiture is to use large apertures and to focus

sharply on the eyes. This has the effect of throwing the ears somewhat out of focus and the background completely so, and serves to concentrate attention on the part of the face normally observed closely. One can imagine without trying it the effect of focusing sharply on the ears.

In cases where detail is a very subordinate part of the picture, the rendering may be made more effective by sacrificing more or less of the fine detail. There are many ways of doing this, for example deliberately throwing a fine lens out of focus, using a poorly corrected lens, or, better, a lens having adjustable spherical aberration, printing with a slight distance between negative and paper, or developing to destroy detail in a process like carbon printing. Each method has a somewhat different effect in the print, and the method used should be chosen with special regard to its particular character. A high class modern lens gives more detail than is effective in the average picture; it gives so much more than the eye can see when viewing the picture as a whole, that the observer is tempted to examine parts, and thereby the general effect is weakened. This is not to say that every picture should have all the detail blotted out, an effect of which one sees far too much in any group of pictures at the present time, as if all that was necessary to make a picture artistic was to blur it. All such devices used without any con-

sideration of their appropriateness serve merely to show that their user lacked judgment.

141. **Distortion from Inclined Plate.**—We are so accustomed to looking horizontally that we interpret every picture as made in that direction. If one takes a picture of a tall building by tilting the camera so as to look up at it, and then holds the print vertically for observation, the building will appear to be falling over. But if the print be tilted, upper part toward the observer, in agreement with the tilt of the camera, a position can easily be found where the representation will be correct, and the building look vertical. But since the habit of looking perpendicularly at the print is so fixed, a picture taken for any other viewing is misleading or escapes interpretation unless there are perfectly obvious guides to the required orientation. Also this requires effort on the observer's part which is not appreciated, so that unless physically impossible pictures should be made with the plate in the camera placed carefully vertical. The lens may be tilted, or shifted up or down, without difficulty in this respect.

142. **Lens Axis.**—If a picture contains a few straight lines it is easy to determine fairly closely where the axis of the lens intersected the plate. Even if there are no straight lines the effect can not be entirely ignored. We ordinarily look straight at what we desire to see, and a picture which repre-

sents something as seen above or below while looking straight ahead will not look natural, that is will require special effort by the observer to interpret it. Hence, one can say that the axis of the lens should fall somewhere near the central part of the picture. Pictures where the lens has to be shifted way up or down to get the subject on the plate, for example tall buildings, are not the most pleasing compositions.

143. **Exposure and Development.**—The exposure should always be within the latitude of the plate except for definite, well-formulated reasons. By underexposure of various degrees it is possible to subdue the shadow detail or block it out entirely, which enables one to imitate moonlight conditions and to emphasize the notan. Actual overexposure offers hardly any results which can not be better obtained by other means. The ideal development is for gamma unity, but it may be varied from (a) when it is desired to over or under exaggerate the actual contrast in the subject, or (b) when the full scale of the printing method is not as great as the range of illumination in the subject so that it is preferred to lessen contrast rather than sacrifice detail at one or other end of the scale, see Art. 86.

144. **Printing.**—The pictorial element is important in the printing. One's choice of the various methods is based on many considerations,—total

scale needed, rendering of detail, tone, surface, ease and certainty of control, labor required, flexibility, permanency. In regard to tone and surface there is one consideration which should never be forgotten; anything which calls attention to the method and away from the picture is thereby condemned. The ideal arrangement is where these details harmonize so well with the picture that to be noticed they must be looked for directly. They should contribute to the pictorial effect, not distract attention from the thing itself. Very brilliant tones are for this reason almost always unsuitable, as also are exceedingly coarse, visible grain and imitation of other fabrics.

The control over the *detail rendered* and the trimming offer however the greater opportunity for pictorial improvement. By the use of a glossy developing paper one can render almost all the detail in the negative, and by successive steps to a coarse matt the fine detail may be more and more subdued. This control however extends to the picture as a whole; it is much more difficult with developing and printing out papers to control locally. It is in these features that platinum, carbon, and gum methods have the advantage, as in development one can make marked local variations. Also with all methods local shading during printing enables

one to control definite areas, and by over- or under-exposing locally reduce the detail.

The natural desire of the beginner is to make his print cover the whole negative; and it is only when the advantages of liberal *trimming* are felt that this attitude is modified. In case one desires a picture of a certain size it is advantageous to enlarge the part of the negative finally selected. To determine this part, experiment by covering the four edges of the print with four pieces of paper and move them to various positions on the print and observe the effect on the picture as a whole. Keep in mind the predominant position the center of interest should occupy, and also the requirements of notan and balance. A careful study of one print you are interested in will teach a great deal. When satisfied mark the print and trim to the marks. In case a white margin is desired, surround the selected part of the negative with black paper pasted to the gelatine, and print through this mask.

145. In mounting try to make the mount serve the purpose of the print and not distract from it. When several pictures are mounted together on one page, choose pictures which form a harmonious group by having some common features—similar printing method, similar treatment, similar subjects. Choose the most interesting and conspicuous one as

the center of interest and group the others around it in balance and to help the central interest.

146. **Conclusion.**—In games of chance and skill like whist, bridge, checkers, chess, or even billiards and pool, the pleasure to be derived from the routine of the game—the mechanical arranging and holding of the cards and dropping one as desired—is largely gone as soon as it is mastered reasonably well. For those who go on, the interest must shift to the intellectual problem of the management,—order of play—of the complex interrelated group of factors,—the cards,—and the checking of one's deductions and inferences by the results achieved—tricks taken. The mechanical part becomes relatively very subordinate except as it retains some of the intellectual problem.

So also in picture making, the pleasure in the mere routine of exposing, developing, fixing, printing, continues only so long as it presents difficulties susceptible of mastery—that is essentially intellectual. When one has mastered the routine sufficiently well that there are no obvious improvements possible, then the work will be laid aside to be called into play when needed for other reasons, unless new methods are experimented with or unless the intellectual problem of the building of the picture is realized. This new problem makes use of the mechanical routine as a means, the facility with which con-

tributes to the solution of the new problem. For this reason the pictorial element dominates photographic exhibitions, relegating methods to the position of means to this end. And the successful exhibitor is he who can use these methods freely and skillfully in the solution of this more complex problem. The next and perhaps final step in the series is when pictures are attempted which tell a story or represent (and thereby transfer) abstract ideas and emotions.

APPENDIX

Development

Through the courtesy of Mr. Alfred Watkins of the Watkins Meter Co., Hereford, England, is printed below his list of plate speeds and development speeds. The numbers apply to the speed of the plate, being directly proportional to the speeds, and therefore inversely proportional to the time of exposure. The letters apply to the development speeds, thus placing all the makes of plates in eight classes. The strength of developer for the same time of development is indicated by the drams of concentrated developer to be diluted to the three ounces. The same company makes the concentrated developer ready for use, and the formula is given in the Watkins Manual.

WATKINS SPEED LIST

Compile solely from actual tests for use with Watkins Meters (any developer), not to compare speed or quality. Exposure speeds are indicated as numbers and grouped; thus 180 means a speed somewhere between 152 and 215.

Development speeds are indicated by code letters, the figures below being drams of two concentrated solutions in 3 ounces of complete Watkins Thermo Pyro-Soda Developer, for 6½ minutes at 60 degrees. This applies to the Time Thermometer.

Where two brands of the same maker are quoted alike they may differ slightly, but samples tested came in the same group.

Development Speeds

	VVQ	VQ	Q	MQ	M	MS	S	VS
Drams............	1	1⅓	1¾	2¼	3	4	5	6¾

Note separate heading for films and color plates.

Development Speeds have nothing to do with Exposure Meters.

The words Simplex, Anti-Halo, or Backed, do not indicate any difference in speed.

Agfa, Ex. Rap	180 MQ
" Isolar	130 MS
" Chromo	250 Q
" " Isolar	130 MS
" " Isorapid	250 MQ
" Iso. Rap.	250 M
Central Ortho	290 MQ
" Spec. Non. Hal.	130 MS
" "	180 M
" Comet	130 M
Cramer Anchor	130 MQ
" Banner	180 S
" Crown	250 S
" Isonon Port.	350 M
" " Com.	250 MQ

Cramer Polychrome	180 MQ
" Spectrum	180 MQ
" Trichrome	180 MQ
" Iso. Slow	180 MQ
" " Med.	180 MQ
" " Inst.	250 MQ
Defender Slow	11 VVQ
Eastman Rapid	130 M
" Extra Rapid	180 M
" Ortho	180 Q
" Spec. Sens	250 M
" " Ultra Rap.	250 MS
Forbes Challenge	90 VQ
Hammer, Record	180 M
" " Ex. Fast	250 MS
" Aurora Ex. Fast	180 MS
" Ortho Slow	45 VQ
" " Extra Fast	180 M
" " Non. Hal.	180 M
Jougla Intensive	130 S
" Violet	180
" Green	130
Seed, 23	90 MQ
" 26	180 MS
" 30 Gold Edge	350 MS
" L Ortho Non. Hal	180 MQ
" Non. Hal	250 MQ
" Color Value	250 M
Standard, Thermic	180 MQ
" Orthochrome	180 MQ
Stanley Commercial	180 MQ
Roebuck Blue	180 S
" Ortho	130 M
Barnet Ordinary	45 M
" Medium	90 M
" Ex. Rap.	250 S
" Studio	250 S
" 550	500 VS
" Press	350 MS
" Spec. Rap	130 MS
" Super Speed Ortho	250 S
" S. R. Red Diamond	350 MS

Barnet Red Seal	250 S
" Med. Ortho	90 MQ
" Ex. Rap. Ortho.	180 MS
" Self Screen Ortho	250 MS
Ilford Ordinary	45 Q
" Versatile Rapid	130 MS
" " Most Rapid	250 MS
" " Ortho	180 M
" Screened Chromatic	180 MQ
" King's Own	180 S
" Chromatic	130 Q
" Empress	90 MS
" Rap. Chrom.	180 M
" Spec. Rap.	130 VS
" Monarch	350 VS
" Zenith	250 VS
" Panchromatic	250 M
Imperial Ordinary	45 Q
" Fine Grain Ord.	16 VVQ
" Sovereign	130 MS
" Spec. Sensitive	250 S
" Spec. Rapid	180 MQ
" Flash Light	350 S
" Ortho Spec. Rap.	130 MS
" Ortho Spec. Sens.	180 MQ
" N. F. Ortho	180 MQ
Lumiere Ex. Rapid (Blue Label)	90 MQ
" Ortho A	180 M
" Ortho B	130 MQ
" Ortho C	90 MS
" Sigma	250 MS
" Ordinary	6 M
" Violet Label	500 S
Rogers Regular	180 M
" Ortho	180 MQ
" " Non. Hal.	180 MQ
Warwick, Gold Label	180 M
" Silver Label	90 M
" Bronze Label	65 M
" Rainbow, Fast	350 M
" " Slow	180 Q
" Warpress	180 M

Wellington	Speedy	180 M
"	Ex. Speedy	350 MS
"	Speedy Iso.	180 M
"	Speedy Portrait	180 M
"	Landscape	65 Q
"	Ortho. Process	32
"	Anti-Screen	180 MS
"	Spec. Ex. Speedy	350 MS
"	Extra Speedy Press	250 MQ
"	Xtreme	500 S

Color Screen Plates

Speed when used with maker's filter.

For Color Plate Meter, also See Meter with bright light and large stop only.

Autochrome	4
Paget	11
Dufay	5
Omnicolor	6

Films

"Roll," "Pack," "Autographic," and "Kinematograph Neg.," same speed.

Ansco Extra Fast	180 S
Austin Edwards	180 S
Ensign	180 MS
Goerz Tenax	130 VS
Kodak N. C.	180 MS
" Ex. Rapid	250 S
Lumiere Plavik (and Block)	130 MQ
" Cinemat	130 M
" Sigma Ortho	180 S
Premo Film Pack	250 S
" " " Ex. Rap.	250 S
Vulcan Ortho	180 S
Pathe Cine	180 MS
Criterion Cine	130 MQ

Just as convenient are the directions issued with the "Agfa" Rodinal (Berlin Aniline Works, 213

Water St., New York), which gives detailed directions, list of development times, temperatures, dilutions, and list of plate development speeds; all by Mr. Watkins. It is one of the best guides available at the present time for the occasional worker. It all applies, of course, only to Rodinal, which is an excellent developer.

Burroughs Wellcome & Co. (35 W. 33d St., New York) publish the "Wellcome Photographic Exposure Record and Diary" yearly. It classifies the plates on the market as to development speeds, and gives also development times, dilutions, and temperature coefficients for use with their ready prepared developers.

The Eastman Kodak Company's book "How to Make Good Pictures" gives full directions as to time, temperature and developer for use with their films. Similar information is given by the Ilford Company for their "King's Own Plate," and by Wratten & Wainwright for some of their plates.

TABLE OF PLATE SPEED NUMBERS

Character of plate	"i"	H & D	Watkins p	Wynne F No.	Scheiner Degree n	E
	6.80	5	7.36	17.2	c	0.272
	5.67	6	8.82	18.9	b	0.227
Very slow	4.85	7	10.3	20.4	a	0.194
	3.78	9	13.2	23.1	1	0.152
	2.84	12	17.6	26.1	2	0.114
	2.27	15	22.1	29.8	3	0.0905
	1.79	19	27.9	33.6	4	0.0717
	1.42	24	35.3	37.7	5	0.0567
Slow	1.10	31	45.6	42.9	6	0.0439
	0.871	39	57.4	48.1	7	0.0348
	0.680	50	73.6	54.4	8	0.0272
	0.531	64	94.1	61.6	9	0.0213
Ordinary	0.415	82	120	69.7	10	0.0167
	0.327	104	153	78.5	11	0.0131
	0.255	133	196	88.8	12	0.0102
Rapid	0.212	160	235	97.4	13	0.00851
	0.157	217	319	113	14	0.00627
	0.123	276	406	128	15	0.00493
	0.097	351	516	144	16	0.00388
Extra rapid	0.076	448	659	163	17	0.00303
	0.060	570	838	184	18	0.00239
	0.047	727	1070	208	19	0.00187

Where E is approximately the minimum exposure in seconds for an open landscape at noon in June at F 16. And,

Wynne F number $= 135/\sqrt{i} = 7.7\sqrt{H \& D}$; $i = A(1.27)^n$
H & D $= 34/i$; $p = 50/i =$ H & D $50/34$,

where "n" is the Scheiner degree and "A" has the value in this case of about 4.4.[1]

[1] See also J. M. Eder, *Handbuch*, vol. 1, part 3, page 240. Wratten and Wainwright, *Descriptive list of dry plates*, etc., page 31. J. M. Eder, *Photographische Correspondenz*, 37, 249 (1900).

PART II

LABORATORY MANUAL

PREFACE

The course in this department has called for one lecture and three laboratory hours per week over one semester, and confers two credits. No student comes to the laboratory for a smaller interval than two hours. The work has been offered always in the second semester because for the latter half, when the student has had some experience, the weather, the lighting, and the foliage are good. The student opinion has been that the work required fully earned the credits—which feeling is to be desired, as the tendency for the outsider is to look upon such a course as a "play" course. The student attitude toward it is well described by one student's immediate objection to omitting anything from the list "but increase the credits."

It has been the practice here to furnish all the supplies and chemicals as well as apparatus, and to charge a laboratory fee. There has been no difficulty about pilfering or extravagance since a definite statement was made of the material to which the fee entitled the student, excess to be separately paid for and all supplies to be delivered only on a signed order. This plan has the great advantage

that the student is not worried about the cost of each experiment and hence skimping on materials. The laboratory can buy to better advantage than the student, and uniformity and reliability in the supplies can be assured.

Physics Laboratory,
University of Wisconsin, 1917.

LABORATORY MANUAL

General Directions

Each student is provided with a small locker for his own special material and apparatus. When assigned this locker should contain:

1 small negative drying rack	2 pads report blanks
1 print album	1 binder for reports
1 empty box, 4 x 5, for negatives	1 box, 4 x 5, dry plates

In the allotment of laboratory places the student will be assigned a partner as a rule. It may not always be possible that the student shall work all his time with one and the same partner. The two will have to compare work done and take up what will be for both the most convenient work next in order in the manual. On account of the time required for the drying of plates and prints as well as long continued washings, it is necessary that the student carry on more than one experiment at once, so that the time will not be spent in idle waiting. When a stage in an experiment is reached requiring a long wait, look back to see that printing and mounting is up to date, and if so start the next ex-

periment. Very much time can be saved by intelligent planning of the work.

Beside the apparatus in the individual locker each dark room should have on its shelves at the beginning of the work the following:

4 printing frames	1 print stick
1 centigrade thermometer	2 wooden tray covers
1 camel's-hair brush	1 negative washer
1 print washer	1 glass funnel
1 measuring glass	1 bottle "soda"
1 tube paste	1 bottle "Pyro"
2 hard rubber trays, 4 x 5	1 bottle acid "Hypo."
2 hard rubber trays, 10 x 12	

As far as possible each article is marked for the locker to which it belongs—and if for any reason any article or bottle is borrowed from another room it must be returned where it belongs.

When the experiments require apparatus not listed above it is to be obtained from the instructor and returned as soon as out of use, or on finishing the day's work.

At the close of the period all apparatus and supplies are to be returned where they belong and the desk left clean and dry for the next group. In the case of spilled solutions, particularly hypo, it must be washed carefully into the sink. The sink must not be made a receptacle for waste paper, etc., as blocking of the drain may flood the whole laboratory. The work for the period will have to be so

arranged as to allow of vacating the bench promptly at the close of the period so as not to interfere with the succeeding group.

The staff reserves the right to impose fines for gross carelessness in the care of the laboratory and apparatus. In general, small routine breakages are covered by the laboratory fee, but in case of serious breakage or injury resulting from gross carelessness, special assessments will have to be made.

As each experiment is finished a report covering the following items is to be handed the instructor,

1. Negative and print data sheet filled in.
2. Negatives and specimen prints.
3. A statement of the object of the experiment with brief theoretical discussion.
4. Statement of the results obtained with a criticism of them.

There are two forms of report blanks, one for routine reports on negatives and prints, the other blank for reports on other work. Every plate should be reported on whether spoiled or not, and the special directions for reports on the particular work followed. In every case with the report is to be submitted the material (negatives, prints, etc.) reported on. These reports with comments will be returned if possible the following day, and the first item of the day's work should be their review and correction. They should be carefully preserved in the

binder supplied for the purpose, and at the end of the semester form the laboratory report, which, together with other submitted material, determine the laboratory standing. These reports, negatives, album, prints, etc., become the property of the student after examination at the close of the semester when the laboratory keys are returned.

Experiment I

The work for the first day consists in making two negatives. Load one plate holder on each side, film side outward, using only the desk ruby lantern in the dark room. The film side may be distinguished by the feel—the finger tips slip more easily on it while they stick more to the glass which feels smoother. Or in the ruby light the film side gives a less sharp reflected image and looks brighter generally than the glass side. Avoid as much as possible touching the film with the fingers. Take the camera, loaded plate holder, tripod, and focusing cloth, and go out with the instructor to make one exposure. Return to the dark room to develop the exposed plate. Mix together equal quantities (total 2 or 3 oz.) from the two bottles marked "Soda" and "Pyro," using a fresh mixture for each plate. Determine the temperature of the mixture with the thermometer and refer to the temperature-time of

development table posted by the sink, for the time for which to keep the plate in the developer. Immerse the plate film side up, remove all air bells, cover the tray, and leave it there this predetermined time, with an occasional rocking.

Rinse under the tap and place in the "hypo" solution in large tray till all the white in the film disappears (5-15 min.). Wash in changing water in the washing box for 15 to 25 min. Discard the used developer but return the hypo solution to the bottle.

While waiting for the plate to "fix" in the hypo, reload the plate holder and repeat the above process, making a second negative.

When washed see that there is no deposit on the film, and dry the plate on edge in the rack. On request the instructor will put out to dry any plate not finished washing at the end of the period, and the drying rack (which is numbered) should be left out ready to receive them.

Submit the negatives when dry with the report on each.

Experiment 2

Repeat Exp. 1 making negatives two at a time. Do not take more than two exposures on one trip out; later when you are more sure of the routine and will not waste plates uselessly use both plate holders. The choice of subjects to photograph is in

your own hands, except for the request not to choose subjects far away or to spend too much time over the choice.

Take a look at the light outdoors today and, considering the subject to be photographed, estimate the exposure. Consult the instructor for confirmation of the exposure chosen.

Experiment 3

At some time in the early part of the semester make up the following solutions used in this work. Bring the three bottles from the shelves in the developing room, return whatever solution they contain to the stock bottles, and make up sufficient of each solution to fill the corresponding bottles. The compositions are as follows:

Stock Pyro		**Stock Soda**	
Water up to	1000 cc	Water up to........	1000 cc
Pot. Metabisulphite	1.4 g	Sod. carbonate (dry)	40 g
Pyrogallic acid	8.0 g	Sod. sulphite (dry)	50 g

Dissolve in the order given.
Attacked by the oxygen of the air so keep stoppered.

Acid Hypo

A		**B**	
Water	2000 cc	Water	200 cc
Hypo	500 g	Sod. Sulphite (dry)	35 g
		Acetic acid (glac.)	30 cc
		Alum (dry)	35 g

Dissolve A and B separately and in the order named, then add B to A with constant stirring and add sufficient water to make 2500 cc.

Paper Developer

Water up to	1000 cc
Metol	0.75 g
Hydrochinon	3.0 g
Soda Sulphite (dry)	12 g
Sod. Carbonate (dry)	21 g
Pot. Bromide	0.4 g

Dissolve in the order named in somewhat less than 1000 cc and after all are dissolved add water enough to make up to 1000 cc. Use about 4 oz. at a time and this will develop 3–4 doz. prints; never return any to the bottle after use. It does not spoil so quickly in the air as Pyro-Soda does.

Make out report on plain report blank of the actual quantities as calculated for the size of bottles used. Did you observe anything which will be of value the next time you make up these solutions?

Experiment 4

Prints on Developing Paper (Gas Light Paper). —Print the negatives from Exp. 1 and 2 on the developing paper. Lay the negative film side up in the printing frame, lay a piece of the paper film side down on the film side of the negative, fasten the back in the frame, and expose the glass side to the light either at the room door or before an incandescent light. As a first trial give 15 seconds at 10 inches from a 40 watt tungsten lamp. Develop in the special paper developer (Motol-Hydro) as the

Pyro-Soda stains the paper. The print should take one to three minutes to develop. If it is dark enough in less than one minute the exposure has been too long. In making a second trial change the exposure by a factor of two or four. The print will never be very satisfactory if the development is cut short in order to avoid too great general blackness. For the best results the exposure must be so adjusted that on a full development the dark parts will be black, not just gray, and the light parts will be as white as the unexposed margin. If the unexposed margin becomes gray, the development has been too long, or the developing light is not safe, or the paper has been unintentionally exposed to white light.

If with an exposure just short enough to keep the white of the print clear the dark parts do not become a strong black, then the negative lacks contrast and will either have to be intensified or a more contrasty grade of paper used. Conversely if with clear whites the dark parts become a dense black in which all the detail has disappeared, then the negative is too contrasty and will either have to be reduced or a less contrasty grade of paper used. Refer to Text, Art. 87.

Rinse the developed print in water and put in the hypo for 15 minutes, then in changing water in the circular washing box for 15-25 minutes. Put out to

dry face up on a clean paper towel. After the excess of water has been removed either by drying or by the towel, the print may be turned film side down and will then dry with very little tendency to curl. Exercise great care not to get any hypo into the print developer as, if the slightest trace gets in, it is liable to stain all the prints with brown patches which may not show till the prints dry. For this reason it is advisable not to put the hands in the hypo at all when printing but to handle the prints in the hypo with the stick provided. The paper is not nearly as sensitive as ordinary plates and may be handled in much stronger light; the hanging red lamp is safe only for short exposures, and weak diffused light is not likely to bother. But if the prints at any time get gray all over, the light may be too strong or the development too prolonged.

Fill in print record of negatives printed, and hand in with the negatives and prints. When returned to you mount in your album a print from each of the negatives. With the tip of the finger rub on a narrow band of paste along the upper and lower edges of the print, and fasten in the book. Number to correspond with the negative.

Experiment 5

To Test Systematically for Correct Exposure make a negative exposed in strips where the expo-

sure of the successive strips increases by a factor of two. In order to make the exposure, choose the plate holder with the slide marked off in half inches, draw the cover slide out till the first mark shows and give the exposure No. 1 in the table (i. e., 1 sec. at stop 8). Then draw out to the second mark and give the second exposure, and so on for the 10 exposures. Note that the last two exposures are alike. The first strip uncovered will get all the succeeding exposures, the second strip all but the first exposure and so on. The fourth column in the table gives the time required at stop 16 to give the same exposure as that actually given by the time and stop of the second and third columns. Then if the whole group of exposures given each strip be added it will give the fifth column, if the times are those required for stop 16. These increase very nearly by a factor of 2. The changes are made almost entirely with the stop as the shutter speeds are very unreliable.

For an ordinary bright day the series of exposures in the table will be sure to have some in the good-exposure range.

Choose a subject as uniform as possible across the plate as, for example, the uniform front of a building or a uniform landscape. Consult the bulletin board for suggestions. Expose one plate, develop and fix as usual. Note the change in char-

acter of the various strips, and make your choice of the best.

Print the negative making good prints from as many of the strips as possible, keeping a record of

TABLE 10

Strip No.	Exposure		Equivalent Time, Stop 16	Total Exposure of Strip
	Time	Stop		
1	1	8	2	4
2	1	16	1	2
3	1	32	1/2	1
4	1	64	1/4	1/2
5	1	128	1/8	1/4
6	1/25	8	2/25	1/6.25
7	1/25	16	1/25	1/12.5
8	1/25	32	1/50	1/25
9	1/25	64	1/100	1/50
10	1/25	64	1/100	1/100

the exposures required in each case. What is your estimate in regard to this plate's latitude of exposure, that is, the factor between the least and greatest exposures both of which give fair prints?

EXPERIMENT 6

Factorial Development.—Go out and make two good exposures, such as suggested by your strip negative. Flood the plate with the usual pyro-soda mixture, noting the exact time with the second hand of your watch. Observe the plate carefully in as

good a red-light as possible for the first appearance of image and note the time required from the flooding of the plate. Cover the tray. Multiply this time required for the first appearance of image by 9 (see text, Art. 33c) to get the total time for which the plate is to be in the developer. Rock the tray only a few times during development. Finish the plate as usual. Repeat the process with other plates. Submit prints and negatives with report.

EXPERIMENT 7

Contact Lantern Slides.—Go out with the camera and make two exposures suitable for lantern slides. Take a lantern slide matt along to tell what size to make the subject on the plate. Develop by factor as in Exp. 6. When dry print these negatives on lantern slides in the regular printing frame, using the exposure time for the first trial as suggested on the bulletin board.

As in the case of plates and paper prints, the control of the character of the lantern slide is best understood by reference to the discussion in Chap. II, and especially Arts. 34, 83, 86 and Exp. 4. It is even more important than in prints that there should be no silver deposit in the clear places (high lights). If the slide is gray all over the exposure has been too long, and if at the same time the dense places are

not dense enough either the development has not been long enough or the negative lacks contrast. Hence in general it is best, as with prints on paper, to give the least exposure which will yield the desired maximum density if the development is prolonged as far as may be without noticeable fogging.

Lantern slide plates are very fine grained and much slower than ordinary plates. A lantern slide should be very much thinner than any negative to be satisfactory; when the picture looks clear and strong in the developing tray it is about right, long before it gets black all over as a negative does.

On account of the small amount of fog produced, the ferrous oxalate developer is an excellent one for lantern slides. The two solutions required are (a) a saturated solution of potassium oxalate and (b) a mixture of 4 parts of water and one part of a saturated solution of ferrous sulphate containing about 2% sulphuric acid. The latter is supplied already diluted. Mix one ounce of each and use for developing only one slide, as it oxidizes rapidly in contact with the air and a precipitate appears. The development starts slowly but when the image begins to appear it comes up rapidly. Since there is no need to fear fog the development may be prolonged for 15 minutes or more. Rinse under the tap and soak for a few minutes in a 1% solution of oxalic acid to remove any

iron which might be deposited in the film. Fix as with the ordinary plates, wash and clean carefully when putting out to dry. Save the spoiled lantern slides so that they may be cleaned for use as cover glasses. Mount the slide by covering the edges of the film with a paper matt and covering this with a clean piece of glass of the same size as the lantern slide and binding around the edges with strips of gummed paper. Consult the instructor for hints as to the easy way to manage this. If the picture requires a different shaped matt, change the shape of the one supplied by sticking strips of gummed paper—the gummed binding strip will usually do—around the sides.

With the report submit the negatives used as well as the finished slides.[2]

[2] The saturated ferrous sulphate solution offers certain difficulties which are, however, readily surmounted. In the presence of water the solid ferrous sulphate hydrolyzes somewhat as it goes into solution, setting free sulphuric acid and leaving undissolved a basic compound. Hence it is economical but not essential to add a per cent. or so of sulphuric acid to the water which is allowed to stand on the crystals. If some scraps of iron, such as iron wire or nails, are added this iron will dissolve slowly, reducing at the same time any ferric salt present, and in this way red effloresced crystals may be used without any hesitation, but the solution will then need filtering. This may be accomplished without tedious waiting by inverting the bottle of solution over the funnel with the neck of the bottle in the funnel. The concentrated solution may be kept for years in glass stoppered bottles, if the stoppers are kept well greased and the solution is never poured from the bottle, but always removed with a pipette.

Experiment 8

Lantern Slides by Reduction.—Set up the concentrated filament tungsten lamp in its box and place the condensing lenses and water cell before the aperture. In the aperture place the frame with the 4 x 5 opening for carrying your negative. See that there is a ground glass between the negative and the condensing lens. This should illuminate the negative uniformly.

Put the 4 x 5 back in the view camera, and set up on the table to make a picture, lantern slide size, of the illuminated negative. Use a kit in the 4 x 5 plate holder to carry the lantern slide plate. Consult the bulletin board for the first trial exposure. The same considerations govern the exposure as in the contact slides.

To become accustomed to the developer usually used for lantern slides develop these in the special hydrochinon developer in which contrast grows fairly rapidly, while it does not stain the film nor give much fog. The best slides are usually obtained by exposures requiring 2-4 min. development.

Hydrochinon Developer

A		B	
Water up to	1000 cc	Water up to	1000 cc
Hydrochinon	45 g	Sod. Carbonate, dry	30 g
Sod. Sulphite, dry	30 g	Pot. Carbonate	90 g
Sulphuric Acid	5 cc	Pot. Bromide	8 g
		Sod. Sulphite, dry	90 g

For use mix A and B in equal quantities.

Fix as with the ordinary plates, wash and clean carefully when putting out to dry. Mount as with the contact slides. If you have time for more than your own negatives exchange negatives with some of the other students.

Report any difficulties encountered. How do you find this developer compares with the ferrous oxalate? Report any difference whatever which you observe.

Submit the finished slides with the negatives used along with the report.

Experiment 9

Halation.—Take three negatives of the same subject using (a) an ordinary plate, (b) ordinary plate backed with black paper. Smear over a smooth 4 x 5 piece of black paper with sufficient glycerine to leave the surface well wet, but not sufficient to run off when against the glass. Lay the plate (glass slide down) on the glycerined paper. Rub gently into contact all over, being very careful not to get glycerine on the sensitive film. Load as usual and expose without unnecessary delay. Wet the plate all over and wash off the glycerine before developing. (c) A double-coated plate whose speed is given on the bulletin board.

Choose a subject liable to show bad halation, such as a lighted lamp in a room, or an interior with sunlight coming in at a window or the fine branches of the trees against a bright background of sky or lake, in general wherever very great sharply marked differences of illumination occur. In all cases the effect is more obvious in the print than in the negative. The test is made particularly severe if the development is prolonged to give strong contrast—conversely for avoiding it. Finish, print and report as usual, paying particular attention to a comparison of the results with the different arrangements a, b and c above.

Experiment 10

Intensification.—Make two underexposed negatives by exposing a plate $\frac{1}{8}$ or $^1/_{16}$ that judged correct. Lessen the exposure by manipulating the stop rather than the time on account of the unreliability of the higher speeds of the shutter. Finish as usual, being particularly careful to wash well (1 hour). The negative should be very thin especially in the shadows.

On the same trip out expose 2 plates as correctly as possible. Better choose different subjects to keep the negatives distinct. In the development cut the

time to about 1/4 of the usual time so that after fixing it will be very thin. Look for any difference observable in the character of these negatives, one pair underexposed, the other underdeveloped.

When they are dry make prints from them. Note any difference in the character of the prints. Such prints are usually flat, that is, lacking in contrast. Refer to the discussion in Chap. II and especially Art. 34; also Arts. 83, 86, Exps. 4 and 7. Contrast grows with the progress of development until fog intervenes. To keep the print from becoming too dark all over lessen the time of exposure as much as possible, and to get the maximum contrast leave in the developer till all development appears to have stopped but not till the unexposed edges of the print become gray. It is possible by varying the method of manufacture to make developing papers which vary greatly in their ability to render contrast. Most makers offer several grades from hard contrast for flat negatives to very soft for hard contrasty negatives and for portraits. The best grade to use depends on the character of the negative and of the subject. An intelligent choice of these papers can hardly be made till the capabilities of one grade are known from experience, and for that reason we will use only the one grade made for correctly exposed and developed negatives.

With your report submit your negatives and the best print from each.

Proceed to intensify [8] these thin well-washed negatives by immersing them first in a solution of mercuric chloride made up as follows. The solution is exceedingly poisonous.

Mercuric chloride	130 g
Hydrochloric acid, conc.	3 cc
Water	1000 cc

The mercury salt dissolves slowly and there is present more than sufficient to saturate the solution. Leave the residue in the bottom of the bottle and use the clear supernatant liquid. Keep the used solution clean and after use return it to the bottle. Allow the plate to lie in this solution till it just shows white through the glass, then remove it to the washing box and wash for an hour. If necessary the negative may then be dried for later finishing. At times the acid in the mercury solution causes the gelatine surface to break up into a mass of lines resembling the cross section of the cellular structure of a plant. The alum in the hypo bath helps to avoid this reticulation but if persistent with the brand of plates used the acid should be cut down to half or less than that given. The mercury chloride reacts with the metallic silver thus

$$HgCl_2+Ag=HgCl+AgCl$$

[8] See text, Art. 64.

Both resulting chlorides are white and insoluble, so that the washing removes only the excess of the mercury chloride and the acid.

Develop these chlorides in the daylight with a developer made by mixing 3 volumes of a saturated solution of potassium oxalate with one volume of saturated solution of ferrous sulphate.[4] Allow the plate to remain in this till thoroughly black, then wash it moderately (15-20 minutes) and put up to dry. Before drying see that the surface of the film is clean by rubbing it gently with the tips of the fingers while flushing with water. If the washing water contains calcium there is apt to be a deposit of calcium oxalate on the surface of the gelatine.

A very great increase of density may be obtained by blackening the plate in a dilute solution of sodium sulphide[5] instead of in the ferrous oxalate. Try one plate. The increase is apt to be larger than is useful except in special cases. Also the process can not be repeated, while when blackened in ferrous oxalate it may be repeated many times, each time about doubling the density.

When dry, print the negatives again and compare these prints with the previous ones. Make out reports by adding the new treatment to the previous history of the negative, and submit prints and nega-

[4] See Exp. 7.
[5] See Exp. 19.

tives again. Finally mount a set of prints in the album.

EXPERIMENT 11

Reduction.—Go out with the camera and make two distinct overexposures, about 4-8 times estimated correct exposure. Finish as usual, and when dry make prints from them. If the incandescent lamp requires too long an exposure go out into the daylight.

To reduce the negatives soak them for a few minutes in acid hypo diluted with its own volume of water. Then remove the negative and add to the solution a few cc of a 10% solution of pot. ferricyanide, say 10 cc to 100 cc of the diluted hypo, stir and immerse the negative again. Watch for appearance of thinning. If none shows in 1-2 minutes repeat the addition of the ferricyanide. The mixture is attacked by the air so that it does not stay active very long.

Proceed the same way till nearly thin enough, when the negative should be put quickly into changing wash water, where the reduction will proceed a little farther during the first part of the washing. Dry as usual. Record the potassium ferricyanide and hypo used for future assistance.

Practice this on some others of your dense negatives. Print these reduced negatives and compare

with the previous prints. Report by adding the account of the treatment to the previous history of the negative and submit negatives and prints with the report. Finally mount the prints in your album.

Experiment 12

Color-Sensitiveness.—Make three negatives of a colored subject—an ordinary colored print—with the view camera in daylight. Use the special 4 x 5 back. Make the negatives on (a) an ordinary plate, (b) an isochromatic plate, and (c) an isochromatic plate with a color screen. The color screen is to be placed in front of the lens and as it absorbs the most effective part of the light the time of exposure with it has to be lengthened. Consult the bulletin board for the necessary increase and also for the relative speeds of the ordinary and isochromatic plates. The latter is sensitive to the red light of the dark room and is better handled entirely in the dark. Keep a record of the plate used by placing a marked piece of paper beside the print being copied.

Develop the negatives all together in the tank for 20 minutes using the pyro-soda diluted in proportion as the time of development has been increased from the usual time. Measure the tank and make up a volume of solution sufficient to completely cover the plates. Beware of using the tap water for the

dilution as it may be very cold; the diluting had better be done with distilled water which has stood in the room, and the temperature of the diluted developer should be near 21° C. During development reverse the plates three or four times to prevent them developing more at one end than at the other. Fix in the tray or in the tank, but before returning the tank to the instructor wash it so thoroughly that you can guarantee that the next user will not have hypo in his developer.

Compare the prints of these negatives with the original subject and in your report discuss the effectiveness of the various colors in recording themselves on the plates under the three different circumstances used. Submit negatives and prints with your reports.

Experiment 13

Spectrum Photography for Plate Color-Sensitiveness.—As light source use the Nernst lamp set up in its box with filament horizontal. Remove the water cell and the condensing lenses and replace the negative carrying board by the board with slit, placing the slit horizontal. With the long focus achromatic lens focus an image of the slit about four feet away and set up the view camera (see diagram) so that the ground glass will be in the same

vertical plane as the image. Remove the lens board and raise the front of the camera. Interpose the replica grating [6] with its rulings horizontal in the path of the light and in such a position that the lower spectrum of the first order will enter the open front of the camera and fall on the ground glass.

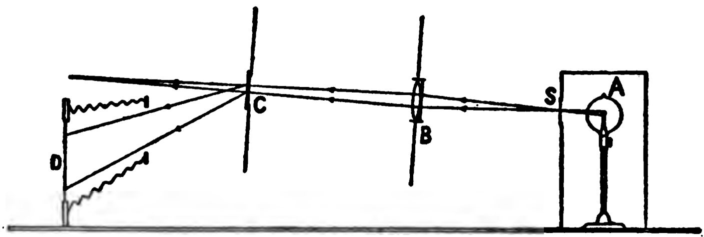


FIG. 50, Exp. 13. Diagrammatic arrangement of apparatus for photographing the spectrum. A is a ribbon filament tungsten lamp or a Nernst lamp; S an adjustable slit set horizontally in the wall of the light tight box enclosing A; B a long focus achromatic lens; C a replica grating; and D the sensitive plate at the back of a view camera without a lens.

Adjust the slope of the beam of light and the position of the grating so that the spectrum will be a convenient length and all of it fall on the ground glass. In the view camera use the 4 x 5 back with long edge vertical. Just in front of the ground glass is a piece of cardboard made to shift sideways to four numbered positions and having a slit through which the spectrum strikes the plate while at the same time the rest of the plate is protected

[6] R. J. Wallace, "Use of Replicas," *Astrophysical Journal*, 24, 121 (1907).

from stray light. Along the side of this slit is a transparent film with a series of numbers which throw a shadow on the ground glass or sensitive film. Make a careful record of the colors at the different numbers so that these numbers on your photograph will enable you to tell the colors which produced the deposit, and make this information part of your report.

Make a series of three exposures on each plate by setting the cardboard screen successively at three of the four positions and at each shift of the screen move the camera sideways so that the spectrum will continue to fall on the opening in the cardboard screen. Make each exposure four times the preceding one and consult the bulletin board for the lowest exposure for each plate. Do this for three plates, (a) an ordinary, (b) an isochromatic, and (c) a polychromatic plate. To keep track of the different plates used, mark them in the corner with a steel point and the pressure mark will develop so as to be visible in the negative. The two latter plates are sensitive to the red light of the dark room and must be handled entirely in the dark. Develop in the ordinary way in the pyro-soda.

Make a print of each negative on a single sheet of paper to show the effect of longer exposure to the different colors. Mark the colors on the print and the exposures on the different strips. Estimate the

different densities along the strip and draw a curve showing the relation of color to density.

Submit negatives, prints and curves, with your reports.

EXPERIMENT 14

Dyeing and Testing of Plates.—The stock dye solution is made up by dissolving 0.1 g of the dye (pinacyanol) in 100 cc of alcohol and this solution keeps well if kept in the dark. For use 15 cc of this solution is made up to a liter with distilled water. This diluted solution is on the laboratory shelves. Soak two of the ordinary unexposed plates in it for 2.5 minutes, shake off all the loose water possible, and place the plates on edge on the rack in the drying cabinet till they are dry. Leave an empty plate box numbered with your laboratory number beside the cabinet to receive your plates when they are dry. As soon as the plates are bathed avoid all light as much as possible as the dyeing makes the plates sensitive to the red light of the dark room. When dry test these plates for color sensitiveness with the same arrangement used in Exp. 12. To test the color screen at the same time make two exposures without the color screen in the path of the incident light and two with. Make the second exposure of each pair

of exposures four times as long as the first, and for the first exposures consult the bulletin board.

As something may possibly have happened to make your dyed plates fail, make two exposures using the color screen on a polychromatic plate.

Develop, fix, and print each plate as usual. As in Exp. 12 draw curves representing the color sensitiveness of the plate—one curve for the ordinary light and the other for the light as modified by the color screen.

Submit negatives, prints, and curves, with your reports.

Experiment 15

Microphotography.—In the discussion on lenses, in the text it is pointed out that the relative sizes of object and image depend on their respective distances from the lens. As the object is brought nearer the lens the image moves away and grows larger. For great enlargements this latter distance becomes unmanageable with the ordinary lens and so a short focus lens has to be substituted. The object glass of a microscope is essentially only an excessively short focus lens. Remove the lens and lens board from the view camera and replace with the microscope with the tube set horizontal. Close the opening around the microscope tube with a black cloth. Set the tungsten lamp and condenser so as to

illuminate the object brightly in line with the tube and focus the image on the ground glass. This may be done with the eyepiece either in or out, with somewhat greater magnification in the former case.

Good illumination depends very greatly on good adjustment of the light. The focusing may be done either by the rack and pinion of the microscope or by shifting the ground glass. Very few microscopes will give a picture 3¼ x 4, all of which will be in good focus at once; either the center or edges will be indistinct (curved image). Also the visual focus will not usually be the photographic focus. The photographic focal length will usually be shorter than the visual, so one errs by setting the ground glass a little too near the microscope.

Use a lantern slide plate in a kit in the ordinary 4 x 5 holder. Consult the bulletin board for details as to exposure. Make two good negatives of different subjects, finish and print as usual.

Submit negatives and prints with report.

Experiment 16

Blue Print Paper.—Put your name on the back of two 8 x 10 sheets of paper [7] to be obtained from

[7] The adherence of both the sensitive materials and the image may be greatly helped by the coating on the surface of the paper. The paper is floated on or passed through a dilute solution of boiled starch or a dilute gelatine solution and dried.

the instructor. Wash the camel's-hair brush thoroughly to be sure that it is free from all remains of developer and with it paint the solution of ferric ammonium citrate and potassium ferricyanide over the paper. This may be done in daylight and it is advisable to spread it as evenly as possible taking particular care that no place is missed. If there is plenty everywhere the unevenness will disappear in the printing and washing. After it is surface dry take it to the instructor to put in the box over the calcium chloride till dry. The composition of the solution is given below.

Print in the sunlight under a good negative. From time to time open one half of the back of the printing frame and examine the print. The image will show clearly and must be overprinted as it bleaches decidedly in the subsequent treatment. A thorough washing in water and then drying completes the print. If the highlights are blue the exposure has been too long, the negative is too thin, or the paper is defective. Test for defective paper by washing it without having exposed it to light when it should wash white. Foggy prints can be improved by a quick bath in a very dilute ammonia solution followed by a very dilute hydrochloric acid solution.

For comparison with your own paper, make some

prints on the paper made by a regular manufacturer.

A		B	
Potassium ferricyanide	15 g	Ferric ammonium citrate	19 g
Water	140 cc	Water	140 cc

Mix equal parts before use and filter if there is any deposit. Discard the mixed solution left over.

Experiment 17

Gelatino-Chloride Paper, Also Called Printing Out Paper (P. O. P.).—Pick out several of your good negatives and expose the P. O. P. glossy surface under them in direct sunlight for 3 to 30 minutes, depending on the negative and the light. The progress of the printing may be judged by lifting half of the back of the printing frame and observing the paper. The printing should be carried distinctly beyond the desired final density, as it bleaches markedly in the toning and fixing.

Wash the print for about 10 minutes in changing water or, better, till the water leaving the print shows no cloudiness. Then tone in a gold chloride bath made by adding 90 cc of water to 10 cc of a stock gold chloride solution from the laboratory shelf. Test this bath with litmus paper and make it neutral or slightly alkaline by adding some of the saturated solution of borax. Immerse the print

in this bath and the color should change slowly from shades of red through purple to black in from four to eight minutes. If the print shows no change in one or two minutes and the bath is neutral or slightly alkaline, remove the print and add a few cc more of the stock gold solution, stir, test for acidity, and replace the print. When toned to the desired color, wash in water for a few minutes, and fix for 10 minutes in a hypo bath whose composition is given below. The ordinary acid hypo will usually ruin the print. Finally wash for about an hour in changing water, keeping the prints well separated. Dry face upward on a towel as they stick strongly if face down. These prints still have the reputation of yielding the best and finest detail.

Report the work done and any observations which would help you to do the work better next time. Prepare at least four prints for mounting finally in your album but first submit them for examination along with the negatives and the reports.

Stock Gold Chloride		**Hypo Solution**	
Gold chloride	15 grains	Water	2000 cc
Water	450 cc	Hypo	180 g
		Alum, dry	60 g
		Sodium sulphite, dry	6 g

and when all dissolved mix with

Borax	25 g
Water, hot	300 cc

and let stand over night. A heavy precipitate will form and settle. Use the clear supernatant liquid.

Experiment 18

Enlarging.—Set up the lamp, water cell, condensing lenses, and negative carrying board as for reduction lantern slides (Exp. 7). Select one of your best negatives and mount it in the window film side away from the light. Set the open back of the view camera up against the negative carrier so that the only light getting into the room has to pass through the camera lens.

Open up the stop in the lens and focus the picture carefully on the vertical board. You will find by shifting the lens vertically and horizontally that there is one position for best illumination. Adjust the size of the picture to suit the sheet of sensitive paper by shifting this board backward or forward and re-focusing. Fasten the paper on the board by using two glass-headed pins each on bottom and on each side, and slip the paper in behind the pins by leaving them just loose enough. Adjust the picture and focus it on a piece of white paper. If a piece of red glass be placed over the front of the lens the resulting red light can be thrown without harm directly on the sensitive paper which will aid in adjusting it in position. When all adjusted, close

the shutter, slip the sensitive paper into position, set the diaphragm, and expose with the shutter. The exposure depends so much on conditions of lighting, size of enlargement, density of negative, and speed of paper that it is a matter of guess and try. Consult the bulletin board for a suggestion as to the first trial exposure. With regard to contrast the same remarks apply in this case as in the case of contact prints (Exp. 4) and lantern slides (Exp. 7).[8]

It will be economical of paper if you make the first trials on ¼ or ⅙ sheets. If one ground glass does not make the lighting uniform put a second in contact with, but ground glass away from, the negative. Note that this paper, usually called Bromide Paper, is very sensitive, the emulsion is much the same as that used on plates, and hence should be exposed only to the safe red light. Develop in the metol-hydro developer in the large tray. Dilute this developer with at least an equal volume of water to slow development. Immerse the paper in the developer by sliding it in face down over the edge of the tray, quickly and steadily. When wet all over the surface, lift out and lay back face up, and keep developer always over the surface. A rinse before the hypo-bath helps to avoid stain, and so also will laying it face down in the hypo and then turning

[8] See also Text, Art. 87.

over. If any part of the print stands up out of the hypo even for a few minutes it is very liable to be stained. This paper is too large for the print washer and will have to be washed by changing it a sheet at a time from one tray to another with constant change of water, say 12-15 changes. Dry as usual on towels.

Submit the negatives used and the enlargements with your reports. State any trouble encountered, the best exposures, and your own opinion of your results.

Experiment 19

Sulphide Toning (Sepia).—May be applied to the contact prints or the bromide paper enlargements, but the bromide paper is much the more liable to spot and blister. Prints which have been thoroughly dried once since making are less liable to spot. The prints fade somewhat in the process and hence require to be printed a little darker than your taste calls for. If you have no spare prints suitable, make some but let them dry thoroughly before proceeding. It is advisable in all cases that the hypo should contain an acid hardening solution, and must have been well washed out of the print. Bleach the print in the solution (formula below) till only a faint image remains. Wash till all the yellowness from the ferricyanide solution has gone.

Immerse in the sodium sulphide solution (formula below) till of an even tint. Wash moderately. Dry.

Bleacher		Sodium Sulphide Solution	
Potassium Ferro-cyanide	40 g	Sodium Sulphide	10 g
Potassium Bromide	10 g	Water	100 cc
Water	1000 cc		

Boil the sulphide solution to precipitate the iron, and filter. Dilute 1-10 for use. That supplied is diluted ready for use.

Submit toned prints with report.

EXPERIMENT 20

WET COLLODION PLATES[9]

Preparing the Glass.—Lantern slide size. Wash first under the tap to remove all coarse dirt, then by immersion for 3 or 4 minutes in boiling hot alkali and soap solution; wash well under the tap, handling the glass entirely by the edges, and rinse in distilled water. Dry thoroughly by warming over a Bunsen flame, holding the plate by the fingers on the edge and keep the plate moving. If you have time to wash several plates and let them dry by themselves on the rack they will be much clearer.

Forming the Film.—As soon as the glass plate

[9] See Foxlee, "Wet Collodion Process," *British Journal,* 54, 483 (1907).

has cooled to room temperature, use the brush to run a streak of the rubber solution about $\frac{1}{8}$ inch wide all around the edge of the plate to help keep the film attached to the glass plate. Then hold the plate horizontal by one corner with the left hand, and pour a generous pool of iodized collodion near but not touching the thumb. Spread the pool by gentle tipping so it flows along the far side of the plate and then toward you along the edge opposite the hand, which usually completes the covering of the plate. The corners are not important but avoid getting any collodion on the under side of the plate or on the holding fingers. To make a thick film allow the collodion to rest horizontally on the plate for 1-2 minutes, then pour off the excess into the bottle again from the near right hand corner, keeping the plate rocking to avoid streaks. The plate must be uniformly coated and free from dust to get good results. All the above can be done in any light but the following must be done in the hanging red lamp light, avoiding long exposures.

Sensitizing.—As soon as the film has dried enough to feel firm on the corners, 2-4 minutes, it is to be placed on the silver wire frame and lowered gently and steadily into the silver nitrate solution in the glass box inside the sloping wooden box. If the edge of the solution stops at any place during lowering, it will leave a mark. Leave in the silver

bath 3-4 minutes. On removing the plate handle it by the edges and if the fingers become stained by the silver nitrate wash thoroughly in water and remove the stain by soaking in the ferricyanide hypo reducer. If any of the developer remains on the fingers or under the nails they will be stained blue by the ferricyanide. The film may become loose from the glass (a) if the glass is not clean, (b) if the glass was not dry, (c) if the film was not allowed to dry sufficiently before placing in the silver solution. On the other hand, if allowed to dry too much the negative is apt to be thin.

Exposing.—Do the exposing in the special plate holder which has the middle partition removed. Put the plate in from the back into the silver plated kit, film side down, cover with two small and one large piece of blotting paper, and then slip the brass plate on top of these and into the spring catch which ordinarily holds the plate. Replace the back slide and expose from the other side. Take care not to handle the plate holder in such a way as to press the hard rubber slide against the sensitive film. Expose in the view camera to a negative illuminated as for reduction lantern slides (Exp. 8). Consult the bulletin board for the first trial exposure.

Development.—Hold the plate as for film making and pour onto the exposed film enough of the iron

developer to cover the film but not enough that any runs off (the adhering silver nitrate and developer intensify the film during development). Make the developer flow gently around the film and the image should appear in about a minute. When development has apparently stopped, rinse the plate under the tap, and fix by pouring on the film some of the saturated hypo solution. Rinse for a minute under the tap which will wash the exceedingly thin film. Thin positives are quite as apt to be from insufficient development as from underexposure. As with gelatine plates overexposure gives a flat picture with deposit all over the film. They are easily intensified either before or after fixing.

Plain Collodion		**Iodizer**	
Pyroxline	9 g	Ammonium iodide	3 g
Alcohol (pure)	150 cc	Cadmium iodide	3 g
Ether (pure)	300 cc	Ammonium bromide	1.3 g
		Alcohol	150 cc

Mix three volumes of the plain collodion with one volume of the iodizer a few days before use.

Iron Developer		**Silver Bath**	
Ferrous sulphate	30 g	Silver nitrate	90 g
Acetic acid	20 cc	Water	600 cc
Water	500 cc	Nitric acid to acid reaction.	

Mount two of the best of your collodion plates as lantern slides, and submit them with an account of the day's work including description of any special difficulties and successes.

Experiment 21

Pictures Showing Clear Distance and Clouds.—Make as many negatives as the time will allow, choosing views showing clouds, blue sky, and distances. Use the color screen and the isochromatic or polychromatic plates. Consult the bulletin board for screen factor and the table in the text (p. 220) for the speed of the plates. Also consult the bulletin board for suggestions for good views. It will save time to develop in the tank.

Report on each plate used and submit negatives and prints.

Experiment 22

Autochromes.—Each box holds two packages containing two plates each. In the package these two plates are placed film sides toward each other with two pieces of thin cardboard in between. One piece of cardboard should be kept against the film (which will help to remember which is the film side) and the plate is to be placed in the kit with the glass side toward the lens and the black cardboard still against the film. This is all to be done in the dark. In focusing allowance must be made for the reversal of the plate by reversing the ground glass or allowing for the thickness of the Autochrome glass plate.

The exposure is to be made through a special color screen. As a guide, four seconds through the screen at 16 in the bright summer sunlight will give a good exposure, and it is to be noted that the latitude of exposure is narrow.

Develop in the special developer (formula below) for 2.5 minutes between 16° and 20° C. The whole development is to be carried out in the dark with the time followed by the light of the red lamp facing away from the tray and the tray covered.

Rinse off the developer by a gentle stream of water from the tap or better still in clean water in a tray, as the tap water is apt to spot the film with solid particles. Then immerse in the potassium permanganate solution and go out into the light. In 3-4 minutes all the negative image will have been dissolved out as shown by the transparency, but the plate will still appear a negative by reflected light on account of the black film under the sensitive film.

Rinse thoroughly and immerse again in the same developer in which the plate was first developed till it all goes black, 3-4 minutes. Rinse again for 3-4 minutes and dry.

After the film is thoroughly dry varnish it by pouring a film of the varnish solution on the plate like a collodion film is made. Better practice it on a glass plate first; mount the plate after the varnish

is thoroughly dry as for a lantern slide so that the film may not get injured.

The film is very thin and very frail, so that it must not be touched through the whole process by anything but the solutions. Breaks through to the color film usually show a green patch around the break. If specks get on the film and they do not wash off under a gentle stream of water, leave them alone, as attempts to remove them will almost inevitably break the film.

In case the finished picture after final development lacks vigor, it may be intensified with advantage in the special intensifier.

The composition of the solutions used is given on the printed slip in each box. The Lumière Company also issue a booklet giving detailed directions for the use of these plates.

Report and submit each plate.

Experiment 23

CARBON PRINTING

Sensitizing.—Brush the colored gelatine film over with the Autotype Spirit Sensitizer solution, using some of the solution poured out in a dish and the piece of flannel tied over the end of the strip of glass. Brush the film both ways lightly, avoiding finger marks, and when the solution has soaked in

(1-3 min.) the brushing may be repeated. Let dry in the room out of strong light for half an hour and then keep in the dry box. The film is ready to print as soon as dry enough not to stick to the negative.

Printing.—The dry sensitized film will usually be rolled up and quite hard and must be unrolled with care and slowly to avoid cracking. The printing is to be done in the direct sunlight or in the light from the electric arc. Since the image is not visible, the progress of the printing has to be followed by the use of a strip of solio paper in the actinometer—a long narrow printing frame with a series of numbers increasing in density. The time of printing is about that required to make a solio print showing its best detail, that is, perhaps half printed for a solio picture. As an approximation try 5 minutes at 18 inches from the arc light. The printing goes on after the exposure has been stopped, so if the exposure is full time, the development should take place within the next hour.

Transfer.—Soak the print and a sheet of single transfer paper in water at room temperature till the print is pliable. Then bring the two faces together, under water, avoiding air bells; lift out, and lay on a pad of blotters. Squeeze them together to get rid of the excess of water. Put another pad

of blotters on top and a weight on that and let stand 5-10 minutes.

Develop by immersing in water at 38-40° C., using the enameled iron tray on the iron tripod, and keep the water at this temperature by regulating the height of the Bunsen flame underneath. After a few minutes' soaking, the soft gelatine will be found oozing out between the edges of the print and transfer paper. They are now to be separated gently leaving the picture on the transfer paper. Soaking longer in the hot water will remove the rest of the soluble gelatine or the process may be hastened by stirring or by laving the print; the most detail is preserved by disturbing only a little.

Clearing.—After development place the print in a 5% alum solution for 10-15 minutes to remove any remaining chromate. Rinse in cold water and allow to dry.

The print will be right-left handed. To make them correct requires another transfer which modifies the above procedure somewhat.

Experiment 24

Characteristic Curve.—Cut down one of the ordinary plates so as to fit the 3¼ x 4¼ holder for the Chapman Jones Plate Tester. Scratch the glass

with a wheel cutter and the film will tear easily. Expose the plate behind the exposing plate for 30 seconds to the candle after the candle has burned for several minutes. Finish as usual. When dry measure the densities of the spots from 1-20 in the photometer. Read over the description of the photometer, page 280, and get from the instructor a negative similar to yours to use in the right hand window. The densities of the numbered spots on the exposing plate are supposed to increase by equal additions, each addition absorbing $\frac{1}{\sqrt{2}}$ the light getting to it so that the exposures decrease by a factor of $\sqrt{2}$. Hence plot the numbered spots at equal displacements on a horizontal axis and the densities of each spot vertically and draw the curve through the resulting points.

Submit negative, numerical data, and curve with your report.

Finishing Up Work

In connection with the grade for the semester, will you please leave in your locker for insoection the following minimum requirement:

Complete reports to date
Album with the full list of prints, including also four P. O. P. prints and two carbon prints.
4 Lantern slides
2 Collodion lantern slides
Autochromes
Two best enlargements

The negatives are not needed. After inspection all these are your personal property. The laboratory keys must be surrendered when the above results of the semester's work are taken into private possession. The laboratory will be open for this at the times posted on the bulletin board.

The written examination is supposed to cover all the work of the laboratory and of the lectures.

APPENDIX I

Laboratory Apparatus

Required for each dark room which accommodates two students at one time.

1 camera, 4 x 5, in case
4 plate holders, 4 x 5, with hard rubber slides
1 focusing cloth
6 printing frames, 4 x 5
1 Centigrade thermometer
1 camel's-hair brush, flat, 1 inch
1 circular print washer
1 plate washer, for 4 x 5 and 3¼ x 4 plates
1 measuring glass, 4 oz.
1 tripod
4 deep hard rubber trays, 4½ x 5½
2 deep hard rubber trays, 10 x 12
1 print stick
2 tray covers
1 glass funnel
1 ruby safe light for plates
1 hanging tipless ruby incandescent lamp
1 large sink, 3 faucets
Group of lockers, 10 or 15 per room
Desk, top preferably covered with sheet lead, to be water tight.

1 drying cabinet. The simplest form is a box with a light tight door and large enough to hold a plate drying rack with a dozen plates. It has to be provided with tortuous passages for inlet and outlet of air and some arrangement for forcing the air through.

In addition to the above each locker needs a collapsible drying rack to hold one dozen negatives.

Special Apparatus

Required Set for Each Two Dark Rooms

1 view camera, 6½ x 8½ standard type with long extension bellows, large removable lens board, and vertical adjustment of lens. The plate holder carrier must be square and removable so that it may be placed either edge vertical, or replaced by other parts.

1 special back for the view camera having ground glass and opening for 4 x 5 plate holder. It requires also the sliding screen described in Exp. 12.

1 high grade modern lens, to cover sharply a 4 x 5 plate.

1 incandescent tungsten nitrogen-filled lamp, 100 watt locomotive headlight type with concentrated filament.

1 water cell arranged to carry a 6-inch condensing lens on each face.

1 light tight box for holding the above lamp and water cell. It requires a door for adjustment and an opening, the inside of which is shaped to fit the backs for the view cameras, and the outside of which is fitted to receive the opening in the back of the view camera itself.

1 back for view camera fitted with simple adjustable slit.

1 back for the view camera made with 4 x 5 opening for carrying a ground glass and 4 x 5 negative.

1 low grade achromatic lens, 30 or 40 cm focal length and 3 or 4 cm diameter.

1 replica grating, second quality, 3 or 4 cm square.

1 color screen, fairly dark, to give unmistakably clear distances and strong clouds.

1 drying box. An ordinary bread box fitted with a glass tray of calcium chloride covered with brass wire gauze.

1 Watkins Bee meter.

8 kits, 4 x 5 to 3¼ x 4.

2 doz. push pins.

1 small iron pot for cleaning the glass in making collodion slides.

1 developing tank, 4 x 5, reversible.

2 enamel trays for holding hot water for carbon printing.

Trimming board, one or two for the whole laboratory.

Chapman Jones Plate Tester, made by Sanger Shepherd

and Co., Holborn, London, W. C., England. One or two for the laboratory.

Scales and graduates for making up solutions.

1 plate holder for collodion plates, made by removing the central septum from an ordinary 4 x 5 plate holder. The 3¼ x 4 plate is held in a brass kit which is silver plated and is arranged to be filled from the back and needs no fasteners, being held by some blotter and a brass plate, 4 x 5, with a finger hole. See Exp 19.

1 dipping bath for the collodion plates. Anatomy museum jars of suitable size are fitted into a wooden box with a hinged cover and with feet arranged so that the box stands with a slight tilt. The plates are carried on a silver wire frame fastened together with silver solder.

1 small single filament Nernst glower.

Supplies per Student

These quantities are necessarily very approximate as they vary materially from year to year.

1 album for 4 x 5 prints

2 pads, report blanks (50 pages)

Dry plates, 3 doz. ordinary
1 doz. isochromatic
⅙ doz. polychromatic

12 doz. developing paper, 4 x 5, medium contrast, semi-matt, thin paper.

1 manilla paper report binder

1 manilla paper envelope in which to hand in reports, etc.

Paper toweling.

1 doz. enlarging paper, 10 x 12

1 doz. printing out paper

2 doz. lantern slide plates

1 doz. lantern slide cover glasses

1 doz. lantern slide matts.

⅙ doz. carbon tissue, 4 x 5, assorted colors.

½ doz. single transfer mount, 4 x 5. These last two items it pays well to buy in the roll and cut up. Autotype tissue and supplies may be bought through George Murphy, 57 East Ninth Street, New York.

½ pkg. lantern slide binding strips.

⅙ blotter, photographic, 19 x 24.

½ doz. blue print paper, 4 x 5.

2 sheets 8 x 10, good linen paper for blue print sensitizing. Size with starch or better gelatine.

2 Autochromes, 3¼ x 4.

Chemicals per Student

Acetic acid, 2 oz.
Alcohol, absolute, 1 oz.
Alum, powdered, 2 oz.
Borax, ¼ oz.
Ether, 1 oz.
Ferrous sulphate, 2 oz.
Glycerine, ¼ oz.
Gold chloride, 2 grains
Hydrochinon, 1 oz.
Sodium hyposulphite, 4 lbs.
Mercuric chloride, 1 oz.
Metol, ¼ oz.
Potass. bromide, 1 oz.
Potass. carbonate, dry, 2 oz.
Potass. ferricyanide, 1 oz.
Potass. oxalate, 4 oz.
Pyrogallic acid, 1 oz.
Silver nitrate, ¼ oz.
Sodium carbonate, dry, 1 lb.
Sodium sulphite, dry, 1 lb.
Spirit sensitizer for carbon printing, 1 oz.

and small quantities of the following:

Ammonia liq.
Ammonium bromide
Ammonium iodide
Benzol
Cadmium iodide
Ferric ammonium citrate
Litmus paper
Negative cotton
Oxalic acid
Potass. metabisulphite
Potass. permanganate
Rubber cement
Sodium sulphide

APPENDIX II

Photometers

There are several types of photometers on the market but they are expensive, often elaborate instruments and hardly suited to this work. A modification of Hurter and Driffield's original arrangement, making use of the inverse square law, can be made sufficiently accurate, simple, and inexpensive. Such an arrangement is described by W. B. Ferguson.[1] His comparison arrangement, however, is not satisfactory and a much better arrangement is substituted here.

Two ways, a ½ inch brass tube and a ¾ by ⅛

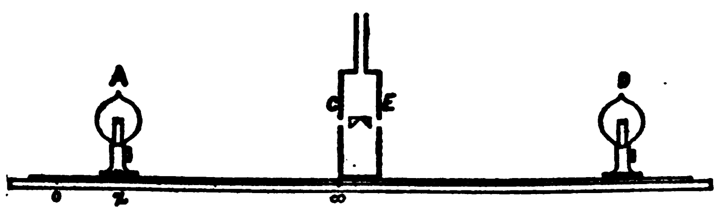


Fig. 51. Bench Photometer.

brass strip, are screwed parallel to each other and four inches apart on a piece of seasoned oak 7 x 1 x 60 inches. Fig. 51 is a diagram of the gen-

[1] *Photographic Journal,* Vol. 52, page 283.

eral arrangement. On these ways are carried two lamps and between them the box with the photometer comparison head. They are held in line by a slotted piece of brass tube sliding on the ½ inch

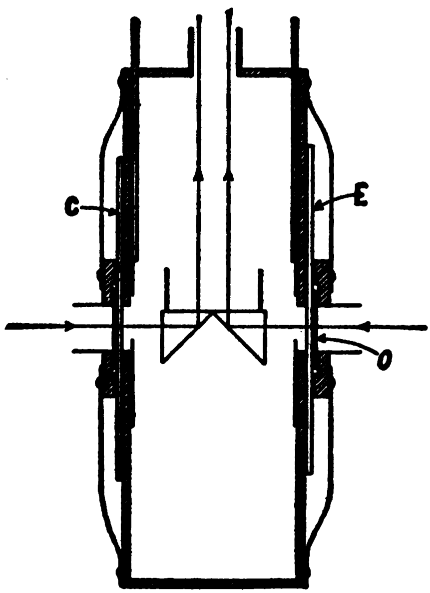


FIG. 52. Central Box of Bench Photometer.

guide. The most satisfactory lamps available are the nitrogen-filled concentrated tungsten filament locomotive-headlight incandescent lamps, and the 100 watt size will give light enough to read all the ordinary densities. They usually run on lower voltage than the lighting circuit so that they are probably best connected in series with each other and

with sufficient resistance to give them their rated current. Automobile headlight lamps of lower wattage or stereopticon lamps of higher are available. The left hand lamp has a pointer on its carriage in the same vertical plane as the filament and the position of the lamp is read on a scale placed parallel to the brass tube. An ordinary meter stick will serve but the readings require a lot of calculating which may be avoided by the use of a logarithmic scale. Below is given the algebra from which a scale may be constructed which will read densities directly.

In the center of the board is set up a rectangular box 6 x 8 x 3 inches, Fig. 52. In the 6 x 8 face toward the lamps are round holes 0.75 inches in diameter set at the height of the filaments. Held in front of each hole by strap springs from each corner of the box is a disc of wood with a 0.75 inch hole in its center, which is covered on the side next the box by a piece of opal glass (O). The negative slips under this disc till the place required is in line with the holes and the springs must be sufficiently strong to hold the negative from falling. Supported from the inside rear wall of the box are a pair of right-angled glass prisms set as in the diagram, which serve as mirrors so that one looking from above sees two images in contact, one from each side of the box. No viewing lenses are re-

quired, merely a tube to place the eye about the distance of distinct vision and to protect from stray light. The line separating the two images may be made almost a geometric line and the conditions for comparison of the brightness of the two images are excellent. Of course the whole inside of the box must be dead black and otherwise completely closed.

An arrangement for varying the visible area of the negative is necessary for adjusting the negative in position and for arranging always to observe only a uniform area. A piece of brass with a vertical V-shaped opening is arranged to slide in grooves inside the box in front of each of the openings. The result is that the observer sees two triangular images with bases together, and the size of the triangles may be readily adjusted by moving the brass V by a rod projecting through the top of the box. To read the densities of the spectrum plates another brass slider is arranged to cut off the apex of the triangular image so that narrow strips across the spectral band may be compared.

Set the apparatus as in the diagram Fig. 51, except that A is at the zero and C at the infinity of the scale. Insert at E a negative whose density is such that the lamp, D, stays on the ways when the first adjustment is made by moving D till the two spots are the same brightness. The better the color

match of the negatives at C and E the more reliable are the settings. To read total density adjust D so that the illumination matches; then insert the plate at C and move A till the illumination matches again, and the scale reading will give the total density. To read the density less fog, glass, and gelatine, place the unexposed spot in C while making the first setting of D and make the second setting as above and the scale reading will be the density less fog, glass, and gelatine.

If the density of the spot which it is desired to read is so great that A can not be moved near enough to C to make a match, it becomes necessary to substitute a spot of intermediate density. Read its density as above, and with all parts in the final positions of the reading, move A back to zero. Readjust for equality by moving D and if necessary changing the negative E, and proceed with the reading of the original spot. In this way as many stops may be put between as are necessary to bring the final reading on the scale, and the density of the spot in question will be the sum of this series of differences. With each shift of the lamp, A, back to zero, the brightness of the image falls off, thus setting a limit to the series unless brighter sources can be substituted.

Let i be the brightness of the image when matched

at X as above. Then in the first setting where there is no absorption

$$i = \frac{S}{OC^2}$$

where S is the strength of a source such that when placed at O it would give the observed brightness at C if there was no loss of light between O and C. In the second setting the image brightness remains the same, being matched with the same brightness at E, but the incident brightness (I) is now

$$I = \frac{S}{XC^2}$$

and

$$\text{Opacity} = \frac{I}{i} = \frac{S}{XC^2} \times \frac{OC^2}{S} = \frac{OC^2}{XC^2}$$

Whence $\quad D^1 = \log_e \frac{I}{i} = 2\,(\log_e OC - \log_e XC)$

Or $\quad D = \frac{D^1}{2.303} = 2\,(\log_{10} OC - \log_{10} XC)$

For this instrument OC is 70 cm and if D be set equal to any particular value, a corresponding value for XC may be calculated from this last equation. A suitable series of values of XC are then measured off on the scale and each marked with its corresponding value of D. It is to be noted that D^1 is the density in absolute units and D the density in an arbitrary unit involving the factor for the base 10. This arbitrary unit is the one usually employed.

To obtain a value for γ (gamma), that is, the slope of the characteristic curve, expose a plate so that the exposures change by a definite known factor, most simply by the use of a plate with a graded series of densities (see Exp. 23). Develop the whole plate alike. Measure the D (always less fog, etc.) and plot D as function of the logarithms of the exposure, that is, plotting equal factors of exposure as equal lengths. Choose two points near the ends of the straight part of this characteristic curve. Calling these two points 1 and 2, it will be evident from Art. 26, and the above discussion that

$$\gamma = \frac{D_2^1 - D_1^1}{\log_e E_2 - \log_e E_1} = \frac{2.303\,(D_2 - D_1)}{2.303 \log_{10} \dfrac{E_2}{E_1}}$$

and the ratio E_1/E_2 is independent of the unit in which the E's are expressed, so that any convenient unit may be used. It is not necessary to determine the inertia, i, nor is it necessary that the extension of the straight part of all the characteristic curves should cut in a point either on or off the axis.

To obtain the development time for any value of γ, plot several values of γ obtained as above, as functions of the time of development used to obtain each value; draw a smooth curve through these points and from this curve can be read the time of development for any desired value of γ, the most useful value being unity.

To obtain the speed of a plate, make a series of known exposures and develop it for the above determined time for γ equal one. Plot the characteristic curve and read the value for the inertia, which will be the reciprocal of the speed. For absolute values of the speed, the exposures must be expressed in candle-meter-seconds and the light source must be described. Where, however, the speeds are to be used for comparison with other speeds obtained in the same way, any unit for the exposure may be used. With plates which have different color sensitiveness, the character of the light source may have a very material effect on the relative speeds.

ORDER SLIP

Name..............................Lab. No.........
Date......................
App. (to be returned)................................
....
Supplies..
....

PHOTOGRAPHY LABORATORY RECORD

Name..............................Lab. No.........

Negative

Number.........................Exp. No.............
Subject...
Character of subject..............................
Date and hour of day..............................
Character of light................................
Time of exposure..................................
Stop used...
Brand of plate....................................
Color screen......................................
Developer...
Time of development..............Temp...............
Character of negative.............................

Print

Time of printing..................Date................
Brand of paper....................................
Character of light................................
Distance from light...............................
Purpose of the work...............................

Conclusions.......................................

INDEX

(4)